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**COTTON**

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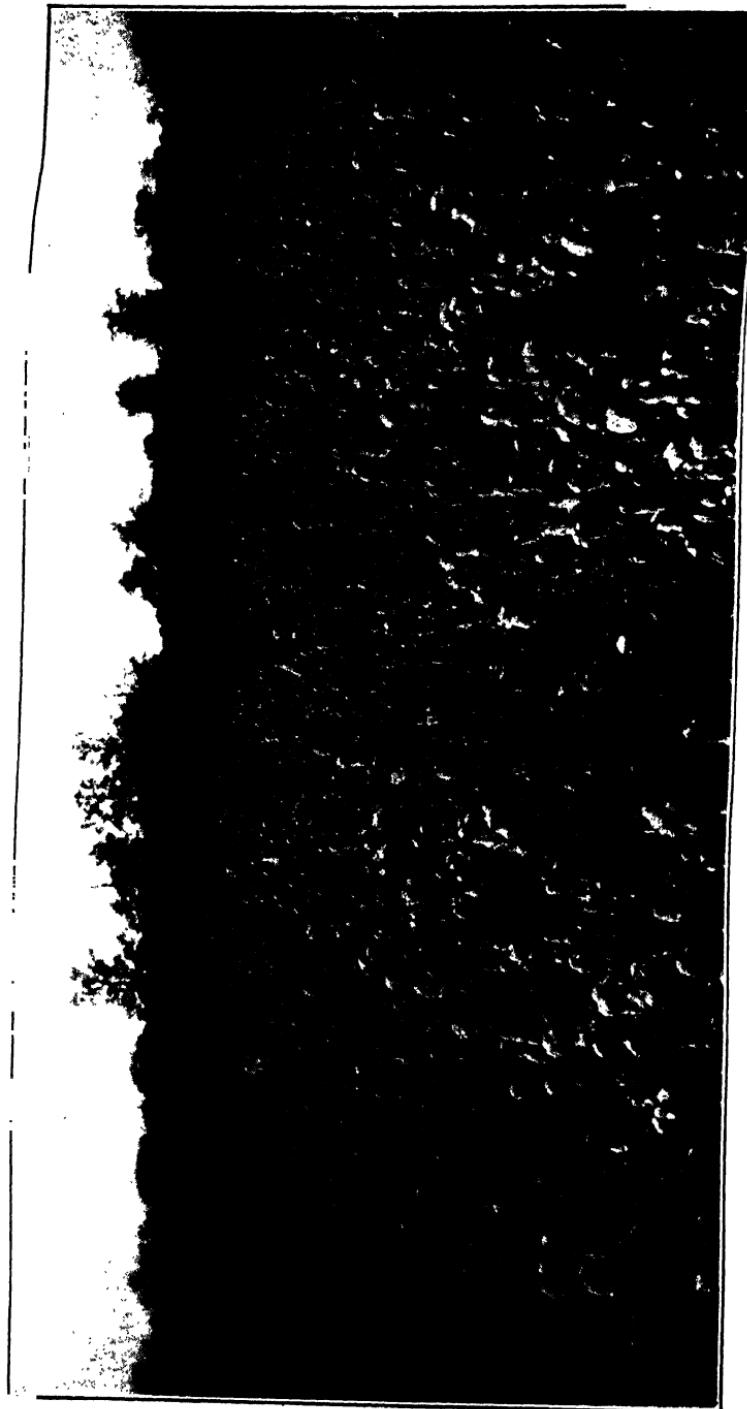
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A field of Upland long-staple cotton with open bolls awaiting pickers. This field made one and one-half bales per acre.  
*(Frontispiece)*

# COTTON

**History, Species, Varieties, Morphology,  
Breeding, Culture, Diseases, Market-  
ing, and Uses**

BY

**HARRY BATES BROWN, A. M., PH. D.**

*Professor of Cotton Breeding, Louisiana State University*

FIRST EDITION

McGRAW-HILL BOOK COMPANY, INC.

NEW YORK: 370 SEVENTH AVENUE

LONDON: 6 & 8 BOUVERIE ST.; E. C. 4

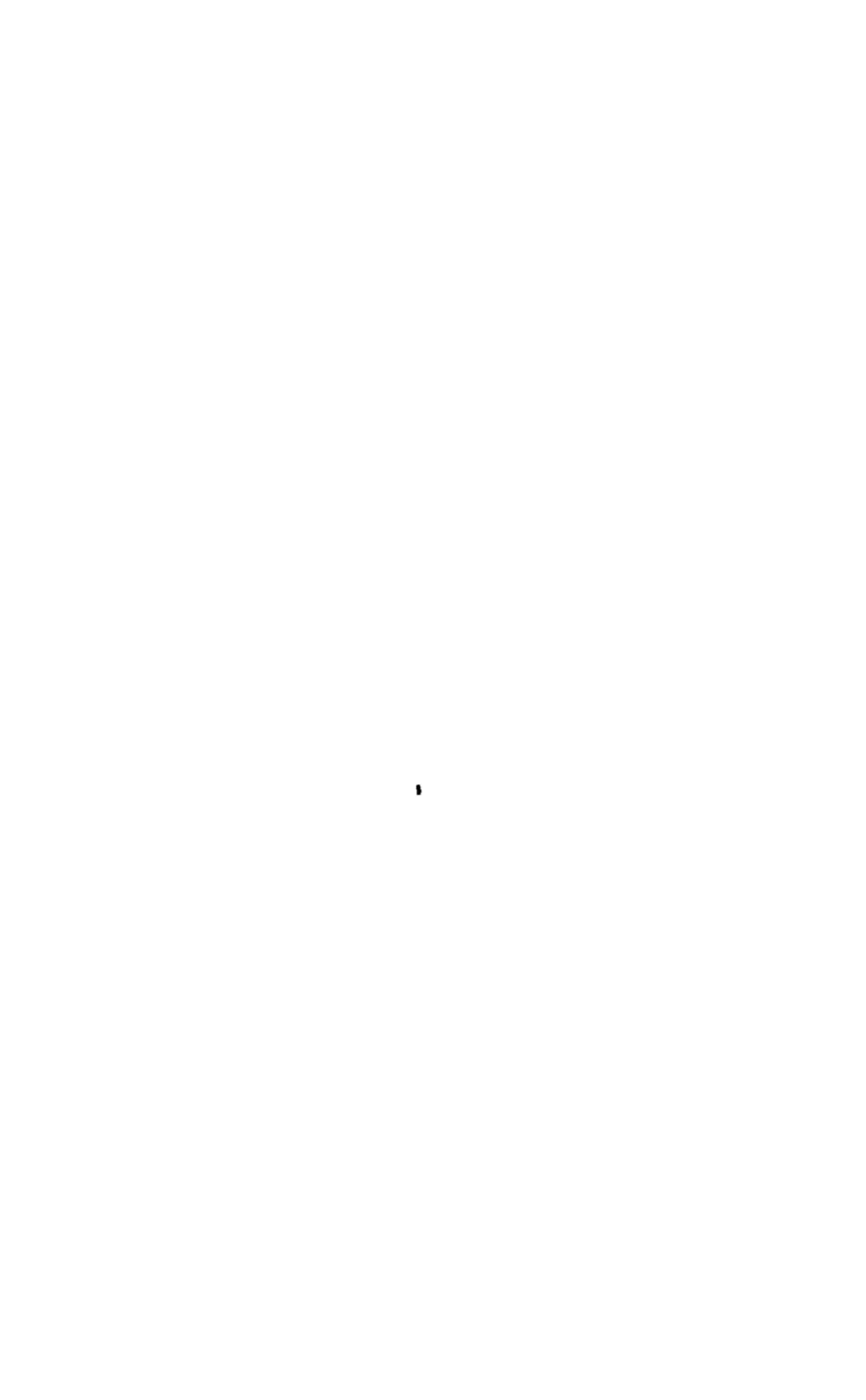
1927

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TO  
MY PARENTS  
JOHN HOLTON BROWN  
AND  
SUE (BATES) BROWN  
THIS BOOK  
IS AFFECTIONATELY DEDICATED



## PREFACE

A book which treats of cotton in its various phases must make at least a brief survey of many fields, for the topic is broad and information on it is widely scattered. Several books have been written on this subject but much of the material in these is out of date on account both of commercial changes and of new information now available as a result of scientific research. It is the object of the present volume to bring together, in compact form, a considerable body of information concerning the most important aspects of cotton and the cotton industry.

In the treatment of the subject a brief historical survey is first made. This is followed by a discussion of the cotton plant in various relationships—its botanical species, agricultural varieties, morphology, physiology, reproduction, and heredity; and a discussion of subjects relating to cotton production—cotton breeding, fertilizers, soils, climate, culture, diseases, harvesting, and ginning; this is followed, in turn, by a review of phases of cotton marketing—classing, cotton marketing proper, and cotton exchanges. Finally, products and uses of different parts of the cotton plant are considered.

Some mention is made of cottons in foreign countries and the conditions under which they are grown, but, in the main, the material here included applies especially to the Upland cotton district of the American Cotton Belt. Some of the views advanced may have been unduly influenced by the writer's experience in Mississippi where he has spent many days in cotton fields engaged in cotton breeding.

The preparation of a work of this type is an arduous task, and one that would hardly be possible of accomplishment at all without the aid and indulgence of associates and friends engaged in different phases of the industry. The writer wishes to acknowledge his indebtedness to all who have assisted in this work, and to mention especially C. A. Tate, Ide P. Trotter, H. M. Smith, and Newman Hancock, who aided in collecting data; Prof. A. W. Palmer, Prof. F. L. Lewton, Prof. W. E. Ayres, Prof. J. M. Beal,

Dr. C. H. Myers, Dr. W. F. Hand, Prof. M. J. Funchess, Dr. J. O. Morgan, Prof. D. C. Neal, Prof. Geo. A. Malony, Mr. L. A. Willis, Mr. Geo. Darden, Mr. R. W. Boys, Mr. D. A. McCandliss, and Prof. G. B. Walker, who read certain chapters of the manuscript; Prof. F. J. Weddell and Dr. R. Y. Winters who very painstakingly read the whole manuscript; Director J. R. Ricks who gave free use of the Mississippi Experiment Station Library; Whitman Davis for very liberal loan of library books; and to Prof. W. Lawrence Balls and others for use of quotations and illustrations from their published works. Acknowledgment of the credit due is made on the page where the borrowed figure or illustration is used. He is also greatly indebted to the officials of the Stoneville Pedigreed Seed Co. for their coöperation which made the preparation of the manuscript possible.

H. B. BROWN.

BATON ROUGE, LOUISIANA.

*December, 1926*

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# COTTON

## CHAPTER I

### HISTORY OF COTTON AND THE COTTON INDUSTRY\*

The origin of the word “cotton” and the date when it was first used in its present meaning are somewhat uncertain. At first it meant merely a fine textile, and the word was broad enough to include flax. Watt,<sup>2</sup> an English authority on cotton, who has investigated the derivation of the word and various words in different languages expressing the same idea, has the following to say: “The Sanskrit work *kárpásá-i*, usually rendered ‘cotton,’ is connected with the Greek and Latin *karpasos* and *carbasus*, but meant originally Spanish flax.” The English word “cotton” came from the Arabic word *qutun*, or *kutun*.

The earliest historical records show man using various fibers in the manufacture of cloth. Wool was the principal fiber used in early times in western Asia and in southern Europe, flax in northern Europe, silk in China, and cotton in India. The inhabitants of the various regions learned in some way to convert fibers into a cloth that would serve their needs.

**When Cotton Was First Used.**—When the cotton fiber was first woven into cloth is not known, but the time evidently antedates history. The first reference in literature to cotton, so far as is known at present, is to be found in a Hindoo Rig-Veda hymn.<sup>3</sup> This hymn was written fifteen centuries before Christ and mentions “threads in the loom,” showing that cotton was already being used in weaving. The ancient Hindoo laws in the religious books of Manu record its use about 800 B.C., but it is to be implied that the plant and fiber had both been known for generations before that date. It was specified in the laws that the sacrificial thread of the Brahman must be made of cotton (*karpasi*).<sup>1</sup> Herodotus (484–402 B.C.) said:

\* Numbered references throughout are to the “References” at the close of each chapter.

There are trees which grow wild there [India] the fruit of which is a wool exceeding in beauty and goodness that of sheep. The Indians make their clothes of this tree wool.

Theophrastus (350 B.C.)<sup>1</sup> gives a little light on cotton cultivation in India at an early day. He says:

The trees from which the Indians make cloth have a leaf like that of the black mulberry, but the whole plant resembles the dog rose. They set them in plains arranged in rows so as to look like vines at a distance.

Nearchus,<sup>1</sup> the admiral of Alexander the Great, who conducted an army along the shores of southeastern Asia about 327 B.C., reported:

There are trees in India bearing, as it were, bunches of wool. The natives make linen garments of it, wearing a shirt which reached to the middle of the leg, a sheet folded around the shoulders, and a turban rolled round the head, and the linen made by them from this substance was fine, and whiter than any other.

From references made to cotton by various early writers, it appears that not only did the Hindoos grow cotton and use it in making cloth from ancient times, but that for 3,000 years India was the center of the cotton industry. Some of the cloth made by the Indians with primitive distaffs and rude looms was not equaled for delicacy and texture until the nineteenth century. Marco Polo, a Venetian, who traveled in Asia in the thirteenth century, mentions the coast of Coromandel (Madras, India) as producing "the finest and most beautiful cottons that are to be found in any part of the world." Others described the Indian calicuts (calicoes) as being

. . . so fine you can hardly feel them in your hand, and the thread when spun is scarce discernible . . . When muslin is laid on the grass to bleach and dew has fallen on it, it is no longer discernible.

Poetic writers of the Orient spoke of these fabrics as "webs of woven wind."

**Hindoo Textile Machinery.**—The machinery used by the ancient Hindoos in ginning, spinning, and weaving cotton was of the most primitive type. The gin was a small roller gin called "churka," consisting of two upright pieces between which were two horizontal rollers so set that they almost touched and to one of which a crank was attached. They had a few longitudinal

flutes on the surface. The cotton seed with lint attached was fed between the rollers on one side. The lint was caught by the rollers and passed on through, but the seed, being larger, could not do so, and were thus separated from the lint. (A gin of this type can be used successfully only with cotton that gins easily, as, for instance, Sea Island or other smooth-seeded varieties.)

The ginned lint was "bowed" before being spun. This process loosened neps or knotted masses of fibers, making the whole mass of cotton loose and fluffy. (Considerable trash and foreign matter were also shaken out. Scherer<sup>3</sup> describes the bowing process as follows:

The bow was an interesting contrivance of elastic wood made still more vibrant by the tension of taut cords. A workman, placing his bow in contact with a mass of lint, would strike the resounding strings with a wooden hammer, so that powerful vibrations forced open the knots of cotton, shook free the small rubbish of the fields, and produced a mass of downy fleece.

After the bowing process the lint was spun into a thread by a woman, who used either a one-thread spinning wheel or simply a distaff. The quality of the thread depended on the skill and dexterity of the fingers of the spinner.

The Hindoo weaver accomplished the greatest wonders of all. Scherer<sup>3</sup> says:

Cotton, having been ginned and bowed and then spun into delicate yarn, was passed on to this magical master craftsman, plying his trade under the friendly shade of a tree. A handful of reeds, with balances suspended from overhanging branches, made up his frail apparatus, the workman sitting in a pit beneath it, his great toes treadling with looped threads, his hands wielding the wide shuttle-batten, the warp being stretched out along the ground.

**Iyths about Cotton.**—During the Middle Ages most of the knowledge of distant countries was obtained from travelers and explorers who had visited those lands. These early voyagers were much interested in producing an effect on their hearers, and were not very careful about the scientific accuracy of their statements. In fact, many strange and fabulous tales were told, among which was the story of the Vegetable Lamb, or Zoophyte, a being part animal and part plant.

Scherer<sup>3</sup> quotes the following description of the Vegetable Lamb of Scythia, or the Borametz of Scythia.

It was in form like a lamb, and from its navel grew a stem or root by which this Zoöphyte, or plant-animal, was fixed, attached like a gourd to the soil below the surface of the ground, and, according to the length of its stem or root, it devoured all the herbage which it was able to reach within the circle of its tether. The hunters who went in search of this creature were unable to capture or remove it until they had succeeded in cutting the stem by well-aimed arrows or darts, when the animal immediately fell prostrate to the earth and died. Its bones being placed with certain ceremonies and incantations in the mouth of one desiring to foretell the future, he was instantly seized with the spirit of divination, and endowed with the gift of prophecy.

Another story was to the effect that there was a little lamb within each boll and the lint within the boll was borne by this little lamb. Sir John Mandeville, a traveler who is said to have set out from England about 1322, mentions this strange phenomenon. He says:

Another passing marvelous thing may be related, which, however, I saw not myself but heard from trustworthy persons. And when these be ripe [referring to the bolls] they burst, and a little beast is found inside like a small lamb, so they have both melons and meat. And though some, peradventure, may find that hard to believe, yet it may be quite true.

Cotton lint or floss resembles fine wool, and those who have never seen a plant producing such material would naturally think that it must be an animal product. Thus it became easy for the travelers to find believers in their highly imaginative tales.

**The Cotton Industry in India during Later Times.**—As has been shown, India very early took front rank in the cotton industry, and was the leading cotton country of the world for perhaps 3,000 years. The natives grew the plant extensively, and made sufficient cloth to supply their own needs and to supply traders, who carried it to foreign lands. With their primitive equipment they were able to weave muslins of such delicate texture that they were not equaled in fineness by that of another country prior to the latter half of the nineteenth century.

Although cotton has been grown in India for ages, progress in improving the yield of varieties and quality of staple has been very slow. The yield per acre at present is less than 100 pounds

## HISTORY OF COTTON AND

of lint cotton, and the staple length is largely less than  $\frac{1}{2}$  inch. The grade is very low because of the large amount of dirt, leaf, trash, etc., in the lint.

The area of India lying within the cotton belt is, according to Handy,<sup>1</sup> 874,880,000 acres, or an area about twice that of the cotton states of the United States. Much of this area consists of very fertile land, but the climate is not so favorable as that prevailing in the American Cotton Belt. A part of the area has scanty rainfall, whereas others parts have too much—as much as 500 inches per annum in some places. The Deccan, or Central India, is the great cotton section of the country. It is an elevated table-land, with splendid fertile soil which holds moisture well. Most of the export cotton is raised in this region and finds its outlet through the port of Bombay. As was shown above, the comparative cotton production of India is low. This might be increased considerably if there were sufficient demand. During the period of the Civil War in the United States, 1861–1865, when the American supply was greatly reduced, there was a temporary increase in production. The estimated yield in 1919 was 5,845,000 bales of 400 pounds each.

For many years the hand looms consumed most of the cotton produced in India. In 1854, a power mill was built at Bombay. This was followed by another the next year and by several more the next few years. In 1861, there were 12 mills in India, and in 1919, 263. These mills, in 1919, consumed 1,952,000 bales, about 42 per cent of the production.

A little more than half the Indian crop is exported. Japan gets more of this than any other country. About a third of the cotton produced is exported in the form of yarn, the bulk of which goes to China. India imports a limited amount of raw cotton from America and a large amount of cotton goods from Great Britain.

**Cotton in China.**—Cotton was introduced into China from India in early times, but there are no records showing the exact date. There was from early days considerable trade with India both by land caravans and small boats moving along the coast of the two countries. Cotton seed naturally found its way into China, but for many years cotton plants were grown only as ornamentals. The Chinese people, until comparatively recent times, were very reluctant to make any change in habits, manner of dress, government, or business; so they continued to use the same fibers for making clothing that their fathers had used, even

though cotton was better and cheaper. It was not until about 1300 A.D. that cotton came into general use, but since that time its use has spread extensively. At present several million bales are produced and consumed annually. Since a large part of this cotton is used in the home and does not reach the market, it is impossible to get any reliable data on the amount produced. The U. S. Bureau of Census estimated the crop for 1921 at 1,175,000 bales of 478 pounds lint each. Some estimates run considerably higher than this.

Very primitive methods of culture are in use in China, the seed being either sown broadcast or planted in hills in patches ranging in size from a few square yards to 2 acres, and cultivated by hand. Much of the land is very fertile, and good yields are obtained. Labor is abundant and the climate satisfactory, but the great need for using the land for food crops will tend to prevent the increase of cotton growing. The main cotton-producing areas are the valleys of the Yellow River, or Hwangho, and of the Yangtze-kiang River.

The varieties grown are mostly of the Asiatic type. They have small bolls of rather low lint percentage, with a coarse staple about  $\frac{5}{8}$  inch in length. Commonly the entire boll is pulled from the stalk and the cotton is picked from the bolls later at the grower's convenience. The lint obtained is said to be clean and white. Recently some American Upland varieties which have been grown and acclimated at the University of Nanking by Prof. John B. Griffing, have yielded well and given an excellent quality of lint. This shows that American varieties, if handled properly, can be grown there to advantage.

The Hindoo churka, or hand-power roller gin, is used in ginning the cotton used in the home, the bow is used for cleaning, and the hand loom for weaving. According to Handy,<sup>1</sup> but little cotton is sold. What surplus there is, is made into cloth by the women of the family and the cloth sold in the neighborhood. Oil is expressed from the seed and used for illuminating purposes. The cotton stalks are preserved for fuel. It is estimated by Todd<sup>4</sup> that the cotton mills of China contain about a million spindles and use about half a million bales of native in addition to a small amount of imported cotton.

China, according to Todd,<sup>4</sup> exports annually about a quarter million bales, most of which goes to Japan, but some to America and Germany. She imports a small amount of raw cotton from

India, and a considerable quantity of cotton yarn from India and Japan.

**Japan.**—Japan proper produces very little cotton, but she has become a great manufacturing country, her mills containing more than 4,000,000 spindles and consuming annually more than 1,500,000 bales of cotton. About 40 per cent of this comes from India, 20 per cent from the United States, and a slightly less amount from China than from the United States.

Korea, or Chosen, which became a part of the Japanese Empire in 1910, is a promising new source of cotton for Japan. Cotton was introduced into Korea from China about 500 years ago, and Chinese varieties and methods of culture were used until recently. When Japan took over the country, much encouragement was given to cotton growing. American varieties were introduced, seed farms were established, and a cotton cultivation association was formed. In 1913, according to Todd,<sup>4</sup> there were 35,000 acres of American varieties in Korea and 100,000 acres of native varieties. It is estimated that in a few years there will be 300,000 acres in cultivation. Japan takes most of the cotton that is exported.

**Indo-China and Siam.**—These countries produce a limited amount of cotton, the most important of which is the Cambodia variety, grown in the province of Cambodia. Within the last few years, this variety has made a splendid showing in parts of India. No figures giving the total production of these countries are available. One of their principal ports, Saigon, exported 19,000 bales of raw cotton in 1912.

**East Indies.**—Cotton is cultivated in all parts of Java, but the total amount produced is not great. Handy<sup>1</sup> estimated the annual production to be about 6,500 bales of 400 pounds each. Much of the cotton grown is used in stuffing cushions, mattresses, etc. A small amount is also grown in the Siam Malay States, which is made into coarse cloth with the primitive home-made machines in use in the homes there. The more attractive imported machine-made fabrics are displacing the homespun garments. A small amount of cotton is exported from the East Indies to Europe.

**Western Asia.**—Cotton is grown in various parts of western Asia, the area being widely scattered and small compared with those in the United States and India. The principal districts are in Russian Turkestan, Persia, and Asia Minor.

Cotton has been grown in parts of western Asia since ancient times. It was seen growing on the island of Tylos in the Persian Gulf by Pliny (23-79 A.D.) and in Arabia by Theophrastus. It was probably introduced into these regions and in other parts of western Asia from India. Until comparatively recently, cotton growing was not a principal industry even with the people that grew it. It was grown on land not needed for such food crops, as wheat, rice, barley, etc., and consequently no great amount was raised. That which was produced was for domestic use only. The high prices brought about by the scarcity during the Civil War period in America, 1861-1865, stimulated the cotton-growing industry everywhere. Russia, after conquering Turkestan, also fostered cotton growing so as to have a greater supply of lint for her mills. The rainfall in Turkestan is so scanty that irrigation must be practiced. Water is supplied by a number of rivers flowing from the mountains to the plains districts. The soils are of clay mixture, which is not easily permeable to water, and are fertile, being enriched by alluvial deposits from the rivers.

Most of the varieties grown in the Asiatic districts just mentioned are native and belong to the species *Gossypium herbaceum*. These varieties have a short, rough staple and are similar to Indian varieties. American varieties have been tried in Turkestan with varying degrees of success. Sea Island has naturally proved a failure, not being adapted to dry, irrigated regions. Upland varieties which have been acclimatized have been more successful. Although primitive cultural methods are in use, the yields are good, ranging, as given by Todd,<sup>4</sup> from 300 to 450 pounds of lint per acre. In 1917, according to the Bureau of Census Report,<sup>5</sup> the cotton production of Russia was 605,000 bales (this was from Turkestan and Transcaucasia). In 1921, the production had decreased to 95,000 bales, owing to the unsettled conditions prevailing. In tranquil times the production might be increased considerably over the former maximum.

Russia has need for all the cotton she can grow, and more. The U. S. Census Bureau Report<sup>5</sup> for 1922 gave the number of cotton spindles in mills in Russia as 7,230,000. Home spinning and weaving call for an additional supply of cotton.

Persia produces annually about 140,000 bales of cotton. The varieties grown are native and similar to the Russian. The cotton grown is of an inferior type and of low grade. On account

of the scanty rainfall, irrigation is badly needed. Private wells are used to some extent. Most of the crop is sold to Russia.

The provinces of Adana, Aidin, and Aleppo in Asia Minor produce a limited amount of cotton. In 1913-1914, this amounted to approximately 150,000 bales weighing 440 pounds each. The climate of Adana is comparable to that of Egypt. The native cottons grown are similar to the Russian. American cottons have been introduced and found to pay better than the native. Most of the product goes to mills in Continental Europe.

**Southern Europe.**—The only cotton-producing area of much consequence in southern Europe is Transcaucasia. This province produced 124,000 bales in 1912, according to Shepperson.<sup>6</sup> The climate, soils, cultural conditions, and varieties used in this region are similar to those of Turkestan.

Greece grows some cotton on the plains of Beotia and in Salonika. Todd<sup>4</sup> reports that the average crop is about 30,000 bales. American, Egyptian, and native cottons are grown. No cotton is exported.

A small amount of cotton is grown in the southern part of Italy and on the island of Malta.

Cotton is said to have been introduced into Spain in the tenth century. Recently an attempt has been made there to revive interest in cotton growing. Shepperson<sup>7</sup> says that 13,000 bales were grown in Spain in 1920.

**Egypt.**—The civilization of Egypt dates back nearly fifty centuries, but no reliable evidence has been found to prove that cotton was in use there prior to 200 B.C. Clothing and fabrics found in ancient tombs were made from flax in most instances, and never from cotton. It seems odd that a country with such an ancient civilization and one so active in the trade of the world should be slow in making use of a valuable plant like cotton. Balls<sup>8</sup> thinks it is strange that no evidence of the use of cotton by the ancient Egyptians has been found and believes it possible that proof may yet be discovered. He says that it may be that some "lucky excavation or casual glance through a microscope will suddenly extend the known history of cotton in Egypt two or three thousand years."

Wild cottons are found growing in parts of Africa, especially in the Sudan. These may be indigenous, but no certainty can be attached to this point since seed may have been distributed by Arab traders who covered the continent years ago. Definite

information on the culture of cotton in various parts of Egypt prior to 1800 is lacking. It is known, however, that cotton has been grown and an excellent quality of staple produced in the upper regions of the Nile for a long period of time.

Definite descriptions of certain species of cotton being grown in Egypt in 1800 and a brief sketch of the cotton-growing industry were made by members of the French expedition that invaded Egypt about that time. Balls<sup>9</sup> gives the following abstract from their writings:

Some cotton fields exist in almost all parts, yet the crop is peculiar to the most southerly portion of Upper Egypt, and to the Delta.

Thebes Province: *G. arboreascens*. Sown at intervals of a metre on ridges between hods, 200 hods to the feddan; bamia and molochieh on the same ground. Sown mostly in April; flowers after 5 to 6 months; first flowers take 90 days to mature. If sown in July, no bolls are open till early March of the following year. Bolls are picked bodily, placed to dry in the sun, and the *écailles* are removed by hand. Fields never bigger than three feddans. Same plant lasts 8 to 10 years. Never topped, but dry branches are broken off, maximum yield in third year being 300 rotls per feddan. Used *aux fabriques du toile du pays* and more highly esteemed than Syrian.

Delta: *G. herbaceum*. Only grown as an annual. Sown in early April after wheat. Three waterings during the 5 months that it remains in the soil, the third being at flood time. Harvest in early September . . . Near Samanoud gives 180 to 240 rotls per feddan. Price 16 pataques per cantar when sea is free; 9 pataques in time of war. In Mansourah province it is resown every year, but not pulled up, the bolls being gathered bodily as they ripen.

It appears that at the time mentioned, or at the close of the eighteenth century, two very distinct species of cotton were being grown in Egypt, one a tree cotton grown in Upper Egypt and the other an annual grown in Lower Egypt, or the Delta district. The latter is thought by Balls<sup>8</sup> to have been identical with the native cotton grown in western Asia.

The year 1820 marks the beginning of a new era in cotton growing in Egypt, it being the year that Jumel's tree cotton was first grown commercially in Lower Egypt. Professor W. L. Balls, formerly botanist for the Khedivial Agricultural Society, has spent several years studying cotton in Egypt and is probably better qualified to outline its history than any other man. He says:<sup>8</sup>

The cultivation of this short-staple Asiatic cotton [the annual species mentioned above] died out in consequence of the economic development of Jumel's plant, and the last trace we find is a record in 1840 stating that it is almost extinct.

The tree cotton from Upper Egypt was next brought forward under aegis of Mohammed Ali, founder of the Khedivate, at the suggestion of M. Jumel, a Franco-Swiss engineer. Taken from the garden of Maho Bey, in Cairo, it was propagated rapidly from the year 1820 under a system of state control, and soon displaced the Asiatic type. The brown, long, strong lint, readily ginned from the almost naked seed, quickly made its reputation with the spinners, and this type of lint has been typical of the Egyptian product ever since.

To trace the origin of the present cultivated varieties from this stock is almost impossible. Still, the following interpretation meets all the facts at present known.

The success of Jumel's tree cotton led to the importation and trial of other cottons, notably Sea Island. Importations of this latter strain, an annual in habit, have continued to the present day. It is not very successful in Egypt, yielding lightly and suffering unduly from "shedding," but the lint is often of good quality, equal to that of Georgia's and Florida's. The state control of the seed supply became disorganized after a time, partly in consequence of Mohammed Ali's military activities, and the inevitable mixing of two seed stocks was accelerated. This mixing, combined with natural crossing, led to the formation of splitting forms, some of which were annual but brown linted, and these gave rise to the Ashmouni stock, or old "Brown Egyptian," which dominated the fields up to 1887. The tree type disappeared in consequence of its greater liability to damage from insect pests, such as the boll worm (*Earias insulana*), which was definitely recorded in Egypt as early as 1876, and also on account of better cultivation obtained with plants of annual habit. The only remaining trace of its influence is the presence of abnormally tall rogues up to four metres in height in the field. The Hamouli variety was possibly an intermediate stage in this process of extinction by artificial and natural selection.

From the Ashmouni stock came the Afifi, in 1887, by selection, probably natural in part, and from this now degenerate complex of subvarieties and splitting forms other varieties have been selected. The Ashmouni stock was driven into Upper Egypt, and has there improved itself until it is now making a reputation anew.

The relatively white lint of the Sea Island stock has always been a feature of at least one Egyptian variety, such as Abyad and Gallini, both extinct, and the modern Abbassi. Gallini in particular, while possessing the bigger boll, higher yield, and "climatic suitability" of its Peruvian-type ancestor, was a very fine cotton, which controlled the fine spinning market for years, until it deteriorated through mixture

and crossing and was driven into oblivion by competition with Georgia's and Florida's, its own ancestors. Gallini has been revenged of late years on its own unnatural ancestors by the modern Yannovitch, itself a single plant selection from the Afifi complex.

The apparent identity of all the modern varieties of Egyptian cotton in external appearance—for even when grown side by side they are scarcely distinguishable—is the natural result of their origin from two related stocks.

The cotton-growing area of Egypt consists of a narrow strip some 550 miles long along the Nile and the fan-shaped delta, containing about 4,000,000 acres, at the mouth of the river. The soil is alluvial and very fertile. The rainfall is so scanty (from 1 to 8 inches) that irrigation must be practiced everywhere. No land can be used unless water can be carried to it from the Nile. The area is thus limited by the water supply available during the growing season. To increase this supply is a difficult matter. Consequently, there is not much chance for increasing the cotton-growing area.

If the land is irrigated properly, the soil and the climate of Egypt are such as to produce an excellent yield of high-class cotton. The average yield for the whole acreage of the country from 1901 to 1921 inclusive was 393 pounds of lint cotton per acre. No other country equals this in yield. The total production averages about 1,200,000 bales of 500 pounds each. The grade is high, because much care is taken in picking and ginning, and the weather for picking is splendid, not being marred by storms or rains. The length, strength, and color of Egyptian cottons, as well as the uniformity of the fiber, are characteristics that add to their value. In length they rank next to Sea Island, ranging from  $1\frac{1}{8}$  to  $1\frac{5}{8}$  inches.

Ginning is done on roller gins at ginneries in the interior towns. Baling and hydraulic pressing are done at the gin, but the bale is rebaled and compressed with steam at Alexandria.

The bulk of the Egyptian crop is exported. Great Britain receives about 50 per cent, the United States about 30 per cent, France about 5 per cent, Germany 5 per cent, and other countries smaller amounts.

**Anglo-Egyptian Sudan.**—This immense area in east central Africa contains much fertile land and gives promise of becoming in time one of the great cotton-producing areas of the world. There is sufficient rainfall in the southern part of the territory for

cotton growing and much of the rest can be irrigated. The yield for 1913 was 12,830 bales.

**British West Africa.**—Native cottons have been grown in West Africa for several centuries, and enough cloth is woven to supply most of the local needs and allow some for commerce. In 1902, the British Cotton Growing Association was organized to foster cotton growing in British territory. Experiments have since been made in Gambia, Sierra Leone, Gold Coast, and Nigeria. According to Todd,<sup>4</sup> results were favorable in most of the places tried, but for lack of funds the work was discontinued in all the districts except Gold Coast and Nigeria prior to 1907.

It is estimated by Todd<sup>4</sup> that Nigeria has an area of 25,000,000 acres suitable for cotton. The soil is fertile, the rainfall is sufficient, being about 50 inches annually, and the supply of labor is sufficient. The hot, dry winds, which blow at periods from the interior of the continent while the plants are fruiting, do considerable damage. Sea Island and Egyptian varieties have proved failures there, but American Uplands do well. There are also native varieties that are about equal to the Uplands in value. The production of Nigeria in 1913 was 16,300 bales. The greatest hindrance to the spread of the cotton-growing industry in this region is lack of transportation facilities.

**British Provinces in East and South Africa.**—Great Britain has several provinces in East and South Africa from which a limited amount of cotton is being obtained and from which larger quantities are expected later. The most important of these is Uganda in the eastern part. This province is said by Todd<sup>4</sup> to have 25,000 square miles suited to cotton growing. In 1913 it produced 26,000 bales. The cotton grown is descended from American long-staple varieties and has good staple. Means of transportation are poor, and consequently it costs considerable to get the cotton to market. Todd<sup>4</sup> considers it doubtful if the production in this province will exceed 100,000 bales at any time in the near future.

Other cotton-growing districts under English influence in East or South Africa are Nyasaland, which produced 6,800 bales in 1913; British East Africa, 1,000 bales; Rhodesia, 700 bales; and South Africa, 100 bales. English companies have done much to encourage cotton growing in these districts, but the production has been small in amount. The natives do not want to work, and carrying the product to market is as great a task as growing

it. The character of the staple produced was all that could be desired.

**Colonies Belonging to Other European Nations.**—France, Germany, Italy, Portugal, and Belgium all have endeavored to encourage cotton growing in their African colonies during recent years. They have distributed seed of improved varieties, offered good marketing facilities, and tried to teach the natives better methods of culture. While the possibilities of future development are great in most of these regions, much remains to be done before any great amount of cotton will be available to the world from them. The greatest hindrance to the industry is lack of means of transporting the products to market.

**Brazil.**—Cotton has been grown in Brazil since prehistoric times and is doubtless indigenous to the country. It was being grown there very generally when the land was discovered by Europeans in 1500. Probably much of the lint used at that time was collected by the natives from plants growing wild. Several writers within the period from 1500 to 1781 mention the production or use of cotton in various parts of Brazil. Claude d'Abberville, a Capuchin missionary in Maranhão from 1612 to 1614, quoted by Handy,<sup>1</sup> in speaking of the natives growing cotton says:

They gather, clean, beat, and spin cotton with much dexterity, and with it make open hammocks resembling nets, and others as well woven and full of figures as if they were the work of better weavers; also aprons in which they carry their children about their necks.

Although grown rather generally, it appears that no cotton was exported prior to the middle of the seventeenth century, and not much was exported before 1781, the year when the first cotton was shipped to England. From that date to 1800 the main supply for England came from Brazil. Handy<sup>1</sup> estimates that the amount of cotton shipped from five of the principal ports in 1800 was 22,116,000 pounds. About this time the United States began to export a considerable quantity of cotton and became a competitor in supplying Europe. This competition checked the growth of the industry in Brazil.

The possible cotton-producing area of Brazil is enormous. Handy<sup>1</sup> estimated in 1895 that the land then available would produce 40,000,000 bales, with a lint yield per acre of only 100 pounds. While this estimate may be high, there is no question

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that the possibilities are great. Pearse<sup>16</sup> estimates that the area suitable for cotton production is greater than that in the United States. There is an immense area of fertile land with an abundant rainfall over much of it, and the means for transportation are much better than in other large undeveloped areas, such as are to be found in Africa. With numerous river systems in the interior of the country, no part is far removed from a natural highway.

Most of the cotton is grown by small farmers. There are no large plantations, because the labor supply is limited. The laborers are paid a low wage and are not very efficient. The cultural methods followed are primitive for the most part. As a rule, nothing is done in the way of preparing the land for a crop except burning off the litter. The land is not plowed except on a few of the best improved farms. When the time comes for planting, seed is dropped into holes made with hoes. The land is hoed over two or three times during the season to keep down weeds and bushes. Notwithstanding this lack of proper culture, some phenomenal yields are reported from parts of Brazil. From 450 to 900 pounds of lint per acre have been reported from São Paulo. The total yield of Brazil for the year 1919-1920 was 582,000 bales. The average yield for the 10-year period immediately preceding was 403,000.

Several different varieties are grown, a part of which have descended from indigenous species. Two or more species are represented. One is a tree cotton known as Maranhão, and another a short-stapled herbaceous kind known as Herbaceo. This is very similar to American Uplands. The tree cotton attains a height of 15 to 20 feet and yields well for 2 or 3 years, or possibly 4 if well cared for. It produces a better quality of cotton than the herbaceous kinds, but the yield is not so good; it suffers less from dry weather and caterpillars. The tree cotton is not grown so extensively as the others, being less profitable on account of the lower yield and the greater expense in picking. The staple length ranges from  $\frac{3}{4}$  to  $1\frac{1}{4}$  inches. The varieties are badly mixed and staple is lacking in uniformity. The grades are low on account of lack of care in picking.

The ginning is almost all done on saw gins run by steam or mule power. Much of the ginning is poorly done, according to Pearse,<sup>10</sup> and the gins are in bad repair and are poorly managed. The local ginners put the cotton in loose bales of 165 to 200

pounds each. Part of the cotton is exported in this shape, but most of it is repacked and compressed at the ports before it is shipped. The export bales weigh about 400 pounds. The ginners advance supplies to the farmers and later buy their cotton. There has always been considerable home consumption in Brazil, and this is increasing. Handy<sup>1</sup> remarks:

There is no more familiar sight to the traveler in the interior of Brazil than that of spinning with the ancient distaff and spindle. Brazil undoubtedly weaves many thousand pounds of her cotton annually in that way.

The number of cotton mills in the country has increased considerably within recent years. Pearse<sup>10</sup> gives the number of mills in Brazil in 1919 as 202, with a spindlage of 1,513,922. These mills consume about two-thirds of the cotton produced. The export trade is with Liverpool principally.

**Peru.**—Evidence points to the conclusion that cotton is indigenous to Peru. There are historical records that show its use there since about 1500 A.D. Pizarro, the Spaniard who invaded Peru in 1522, found the natives clad in cotton garments. Mummy wrappings and fabrics found in tombs indicate the use of cotton many years previous to that date. The Spanish invaders were looking for gold, and consequently paid but little attention to the cotton industry discovered, and did nothing to foster it. Statistics on the production of cotton in the country for the next 300 years are not available, but doubtless enough cotton was produced to supply local needs, and, during the latter part of the period, some for export. In 1862, according to Handy,<sup>1</sup> 341,243 pounds were exported to Liverpool; in 1865, the exports had increased to 4,145,260 pounds; in 1892, to 6,000, 000 pounds. For the year 1921, the total production, according to the U. S. Bureau of Commerce,<sup>5</sup> was 157,000 bales. The increase in production since 1892 was phenomenal.

The cotton-growing lands of Peru are in numerous small valleys that run from the Andes Mountains toward the ocean. These valleys have a rich alluvial soil. The rainfall is so scanty that irrigation is necessary, but that is fairly easily accomplished, for there is a river flowing through each valley, fed by melting snows from the mountains.

Transportation is a relatively simple matter, since the cotton-growing areas are not far from the ocean and some of the valleys

are supplied with railways. The cotton lands are in plantations varying from 500 to 5,000 acres, and are owned by Peruvians. Most of the labor is done by Indians, who are considered satisfactory laborers, and are paid a fair wage, about 65 cents a day. Chinese and Japanese laborers have been tried, but were not found to be as desirable as the natives.

The acreage for 1910, as given by Todd,<sup>4</sup> was 148,000 acres. The yield that year was 93,000 bales. This is more than a half bale to the acre and is a good yield. On some of the better plantations an average yield of 500 pounds lint per acre is reported.

The larger part of the ginning is done by so-called up-country gins, to which the seed cotton is brought in from the farms, usually on the backs of mules. Some large plantations have their own gins. Certain cotton-importing firms have local representatives, who buy cotton from the gins and plantations. The gin bales are not compressed before shipment. About 90 per cent of the Peruvian production is exported, the United States getting 34,000 bales in 1922. The prospects for Peru as a cotton-producing country are bright. Although the area suited to cotton growing is somewhat limited and all of it requires irrigation, a very much greater amount may be grown than is produced at present. Todd<sup>4</sup> estimates that the possibilities are as great as in Egypt, which produces annually over a million bales.

**Other South American Countries.**—In addition to the countries mentioned other South American countries produce limited amounts of cotton. Several of these are apparently capable of yielding a much larger quantity than is now produced. Of these countries Argentine is the leader. In the northern part of this country there are extensive areas of fertile land, the temperature and the rainfall of which are well suited to cotton. The chief limiting factors are shortage of labor and the production of other crops that are very profitable. The estimated area in cotton in 1920 was 38,000 acres. Primitive cultural methods are in use, but splendid yields have been reported in some instances, some being as great as 500 pounds of lint cotton per acre. Paraguay, Uruguay, and Chili are also producing a small amount of cotton, the total yield not being more than a few thousand bales. The production of Uruguay for 1913 was given as 10,000 bales and that of Chili as 1,000 bales. Colombia, Venezuela, and Guiana also produce cotton in small amounts, but most of it is

used by local mills and in the homes. Guiana formerly exported considerable cotton. Todd<sup>4</sup> reports 16,000 bales in 1827.

**Mexico.**—It was estimated by Ruiz (quoted by Handy<sup>1</sup>) that the annual production of cotton in Mexico at the beginning of the sixteenth century, or prior to the invasion by the Spaniards led by Cortez, was 116,000,000 pounds. Under Spanish rule the production declined, but has continued in a limited way in all parts of the country from that day until the present. About 1860, there was some increase in interest due to the stimulus of high prices brought on by the Civil War in the United States. Production continued to increase somewhat during the next three decades. In 1892, Ruiz estimated that the annual production was 50,000 bales. The U. S. Census Report<sup>5</sup> gives the production for Mexico for 1921 as 126,000 bales.

The area of Mexico is somewhat greater than that of the Cotton Belt in the United States, and much of the territory is suited to growing cotton. There is plenty of fertile land, with either sufficient rainfall or rivers from which irrigation water may be drawn, and the population is estimated by Todd<sup>4</sup> to be over 15,000,000. The natives consist largely of Indians, peons, and mixed breeds, who are, Todd<sup>4</sup> thinks, superior to the American negro as laborers in the cotton fields. Biaconi, quoted by Handy<sup>1</sup> says that, if all the land suitable for the purpose were put under cultivation, the Mexican republic might easily become a rival of the United States in the production of cotton. Under conditions as they exist, however, the country does not produce enough cotton to supply its own needs. In 1920, according to Shepperson,<sup>7</sup> there were 750,000 cotton spindles in Mexico. There are several native varieties of cotton in Mexico, descended doubtless from indigenous wild species. At least three of these have been introduced into the United States, Kekchi, Acala, and Durango. The last two are now being grown extensively. They have staple  $1\frac{1}{16}$  to  $1\frac{3}{16}$  inches in length and of excellent character. Egyptian cotton has been grown with success in the state of Nuovo Leon.

The principal cotton-growing regions in Mexico are in the states of Chihuahua, Coahuila, and Durango. If Mexico can put down domestic strife and encourage her people in agricultural pursuits, she may yet become one of the great cotton-producing countries of the world.

**Central America.**—Small amounts of cotton have been grown in Nicaragua, in Honduras, and in other Central American coun-

tries. It is thought that the lands of these states are adapted to growing cotton, and may, in course of time, be of some importance in the world's production.

**West Indies.**—Cotton is indigenous to some of the West India islands, and is now and has been for many years cultivated to a limited extent on most of them. In 1801, the West Indies produced 25,000 bales. Up to 1820 the production exceeded that of the United States. Since then it has decreased considerably. The principal variety grown is Sea Island. Yields are said to range from 100 to 300 pounds of lint per acre. On many of the islands the length of staple and the quality of fiber are considerably below that of American Sea Island. St. Vincent produces the best quality of staple. The total production of Sea Island in the West Indies in 1912, according to Todd,<sup>4</sup> was 6,026 bales. Accurate statistics on the production of many of the islands are lacking.

The West India Islands are capable of producing much more cotton than they do. Greater profits from other crops which require less labor mitigate against cotton production.

**South Sea Islands.**—Many of the islands of the Pacific Ocean produce cotton on a small scale, or can grow cotton, but the amount actually made is too small to be of much consequence.

Australia can also grow cotton, but up to the present the industry has not flourished in that country, partly because of lack of labor.

**Cotton in the United States.**—American cottons are more or less of hybrid origin; like the American people, they are a product of the "melting pot." For about 300 years different varieties and some different species have been brought to the Cotton Belt from all parts of the cotton-growing world. The various cottons have been allowed to mix and cross. Coming from the resulting complex of hybrids are the forms we have today. While it is possible to trace to some extent the history of a few varieties, such as Sea Island, Pima and Yuma (the American-Egyptian varieties), and perhaps one or two recent importations from Mexico, (Acala, and Durango), the botanical history of the great mass of varieties is a puzzle that will probably never be solved.

**Indigenous Cottons.**—De Vica, quoted by Hammond,<sup>11</sup> reported in 1536 that he found wild cotton plants growing in territory now within the states of Louisiana and Texas. Similar

reports have been made by others, but none of the reports have been authenticated by qualified persons; consequently, it is very doubtful if any species of cotton is really indigenous to any part of the American Cotton Belt, the land that produces the major portion of the world's crop today.

*Introduction in the American Colonies.*—Cotton was introduced into the English colonies very soon after the settlements were first made. Indeed, there is some evidence that cotton was grown in the Virginia colony in 1607, the year the colony was established. In 1621, cotton wool is listed as being worth 8 pence a pound. Cotton production was held in check in this colony by the extreme profitableness of tobacco culture. Later in the century considerable cotton was grown and made into cloth for home use by the planters.

Handy<sup>1</sup> mentions cotton being grown by a colony of English at Cape Fear, in the Province of Carolina in 1664, quoting:

But they have brought with them most sorts of seeds and roots of the Barbados, which thrive in this most temperate clime . . . They have indigo, very good tobacco, and cotton wool.

Cotton is mentioned as being one of the products of South Carolina in 1666, and of Louisiana, which then included Alabama, Mississippi, and Louisiana, in 1728.

The colony of Louisiana . . . was in a flourishing condition, its fields being cultivated by more than 2,000 slaves in cotton, indigo, tobacco, and grain.

Handy<sup>1</sup> further says that cotton seed were planted in Georgia in 1734, being sent there by Philip Nutter, of Chelsea, England. Trench C'oxe, of Philadelphia, mentions cotton being grown as a garden crop on the eastern shore of the Chesapeake Bay in Maryland in 1736.

Many other similar references to the growing of cotton in the colonies may be found in literature. It will suffice to say that the cotton-growing industry in this country advanced slowly. Seed was brought in at divers times and from various regions, among which may be mentioned the Barbados and other islands of the West Indies, Siam, Mexico, and the Levant. Most of the cotton produced was used in making homespun clothes. Thomas Jefferson, writing in 1786, said:

The four southernmost states make a great deal of cotton. Their poor are almost entirely clothed with it in winter and summer. In

winter they wear shirts of it and outer clothing of cotton and wool mixed. In summer their shirts are linen, but the outer clothing cotton. The dress of the women is almost entirely of cotton, manufactured by themselves, except the richer class, and even many of these wear a great deal of homespun cotton. It is as well manufactured as the calicoes of Europe.

Most of the early experiments with cotton culture were made with short-staple cotton. Mrs. Kinsey Burden's attempt in 1788 to grow Sea Island Cotton on Burden's Island is considered by Handy<sup>1</sup> as being the first trial of Sea Island in South Carolina. Mrs. Burden's cotton failed to mature, which failure was probably due to the variety, Bourbon, not being suited to the climate. A successful attempt at growing Sea Island was made near Beaufort in 1790 by William Elliott.

*Exports.*—Prior to 1793, there were no satisfactory cotton gins in use in the colonies. Most of the lint was picked from the seed by hand. This was a very slow, laborious process. A man could pick off only 1 or 2 pounds a day. On account of this extra labor, there was not much profit in growing cotton for sale or export. The labor necessary for producing the small amount needed for home weaving was not so noticeable. The few gins in use were very similar to the "churka" wooden roller gins used in India centuries before. Under such conditions it is easy to understand why the cotton exports were limited. Dana, in "Cotton from Seed to Loom," mentions one, Samuel Auspourguer, a Swiss living in Georgia, as carrying a sample of cotton to London in 1739. This is taken as the first export. Various other shipments, made at irregular periods, are mentioned, but none of them made prior to 1787 contained more than 17 bales. In 1788, 58,500 pounds were exported to Liverpool; in 1789, 127,500 pounds; in 1791, 189,500 pounds; and in 1792, 138,328 pounds.

With the invention of Whitney's saw gin in 1793, a new era started in the cotton industry in America. The production, exports, and domestic consumption all increased with rapid strides following the introduction of this new labor-saving machine. In 1790, 889 bales were exported; in 1800, 91,716; in 1820, 449,257; in 1840, 1,313,500; in 1860, 3,127,568; in 1880, 4,589,346; in 1900, 6,538,000; in 1920, 6,362,000.

*Cotton Manufactures.*—The English government discouraged weaving and the making of cloth in the colonies on the theory that a development of that industry would work to the detriment

of the spinners in the mother country. Spinning and weaving in the homes were not prohibited, but there were no factories during colonial days. The first cotton mill was built in 1787, at Beverly, Mass. Others were erected soon after in the New England and middle Atlantic states, and one at Statesburg in South Carolina. Until 1815, only carding and spinning were done with power machines, the weaving being done on hand looms. Spinning and weaving in the home continued in the South for many years after factories were built.

The number of mills increased rapidly. In 1831, there were 801 cotton mills in the country, in 1860, 1,091 mills with 5,235,727 spindles; in 1898, 17,450,000 spindles; in 1910, 28,500,000 spindles; in 1920, 34,500,000. Within the last two decades the increase in spindlage has almost all been in the southern states. From 1898 to 1920, the number in the northern states increased from 13,000,000 to 19,000,000 while in the southern states during the same period there was an increase from 3,000,000 to 15,000,-000. It is very evident that the movement is toward the cotton-growing area. For the past several decades the percentage of increase in spindleage in Great Britian, the greatest spinning country in the world, has been considerably less than that of the United States. The United States is now consuming 50 per cent of its production. In 1900, it did not consume more than 33 per cent, and before that a still lower percentage.

*Area and Divisions of the Cotton Belt.*—The American Cotton Belt contains about 700,000 square miles of land, but less than 10 per cent of this area is actually being cultivated in cotton.

The Cotton Belt contains five more or less distinct districts or divisions. The old Sea Island growing region may be designated as the first district. This covers parts of South Carolina, Georgia, Florida, and islands along the coast. This district is in a transition stage at present. Sea Island cotton is being discarded on account of heavy boll-weevil depredations, and uplands are being substituted. Meade, an Upland variety with a staple much like that of Sea Island, is being grown to some extent. This region is thought to be especially well adapted to Sea Island on account of the very humid atmosphere.

A second area, which may be called the "short-staple district," includes North Carolina, western South Carolina, northern and western Georgia, Alabama, and the hill-land portions of Mississippi, Louisiana, and western Arkansas. This section is some-

what broken and subject to erosion. Much of the soil is red clay and rather unfertile. The big-boll, short-staple varieties seem to be best adapted to this region.

A third area is the Delta district. This includes the belt of alluvial land along the Mississippi River and other rivers emptying into it. The major portion of the district consists of a broad belt of alluvial soil between the Yazoo and Mississippi rivers. This land lies in northwest Mississippi and is usually designated as "The Delta." Parts of Arkansas, Louisiana, and Missouri, also belong to the Delta section. The rainfall here averages about 50 inches a year and the soils are deep, fertile, and level. This region seems to be especially adapted to long-staple Upland cotton.

Texas, Oklahoma, southeastern New Mexico, and western Arkansas form a fourth district. This area has rather light rainfall and much hot, dry weather. Only hardy, vigorous-growing varieties do well here. The principal cottons grown are the big-boll, medium-length staple varieties, such as Triumph, Rowden, and Lone Star.

The Imperial Valley in California and Salt River Valley in Arizona may be said to form a fifth division of the Cotton Belt. The cotton here can be grown only under irrigation. Pima and Yuma strains of Egyptian cotton, and certain Upland varieties are grown.

*Yields.*—The yields in the United States vary considerably in different years and in different sections. They are naturally low in places where boll-weevil infestation is heavy. In 1921, the average for Missouri, a weevil-free state with small acreage, was 325 pounds of lint per acre. The average yield of North Carolina, a state typical of the short-staple area where weevil damage was slight, was 264 pounds of lint per acre. The yield for Georgia in 1921 was 90 pounds per acre. This represents a short-staple state with heavy weevil infestations.

Arizona and California, in 1921, produced 242 and 258 pounds per acre, respectively. These were weevil-free, irrigated districts.

Texas produced 98 pounds per acre, in 1921, and Oklahoma 104 pounds. The production for the whole state of Mississippi was 148 pounds, while that of the long-staple area in the Delta was more than 200 pounds. The average production of Sea Island in the Sea Island district in pre-bollweevil days was 125 pounds of lint per acre. The average yield for the whole Cotton

Belt in 1921 was 124.5 pounds; for 1920, 178 pounds; for 1919, 161 pounds; for 1918 and 1917, 160 pounds.

The total baleage for the whole belt in 1921 was 7,953,641 bales; in 1922, 9,762,000. The 5-year average for the years 1916 to 1920 was 11,930,641 bales (see Chap. XXV for further data).

*Length and Character of Staple.*—According to the U. S. Census Report,<sup>5</sup> more than 90 per cent of the total crop grown in the United States has a staple length less than  $1\frac{1}{8}$  inches, or, in other words, it is short-staple cotton. In 1920, 1.5 per cent of the crop had a staple length  $1\frac{1}{4}$  inches or above; 8.3 per cent,  $1\frac{1}{8}$  to  $1\frac{1}{4}$  inches; and 90.2 per cent under  $1\frac{1}{8}$  inches. The 1919 figures were very similar, the total per cent of short cotton being 91.2. In 1920, Arizona led the states in the production of staple cotton  $1\frac{1}{4}$  inches or over in length, with 82,000 bales. This was from American-Egyptian varieties. Mississippi produced more cotton  $1\frac{1}{8}$  to  $1\frac{1}{4}$  inches in length than any other state—252,000 bales. Much  $1\frac{1}{8}$ - and  $1\frac{3}{16}$ -inch cotton is grown in the Mississippi Delta. Texas led in the production of short cotton by a wide margin, its production in 1920 being 4,091,000 bales.

In the Cotton Belt, weather during the harvesting season is usually dry and favorable for picking, and as some care is taken by the pickers to avoid getting trash and leaf in the seed cotton, the grade of American cottons compares favorably with that of most of the cotton produced elsewhere. The staple in uniformity and character is also better than that found in several other countries, such as India, China, Brazil, or the Levant; yet there is still much to be desired. At present much interest is being taken in new and improved varieties, and numerous seed-breeding farms have been established. With the use of more good seed, advancements are sure to come.

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## CHAPTER II

### TAXONOMY OF THE COTTON PLANT

Cotton belongs to the Mallow family, or Malvaceæ, which has representatives in nearly all parts of the world, but its species are most abundant in the tropics and in warm regions. Several plants of economic importance are included in the family. In addition to cotton, or *Gossypium*, which is the most important, may be mentioned the Deccan hemp (*Hibiscus cannabinus*); okra (*H. esculentus*); mallow (*Malva sylvestris*); and marsh mallow (*Althaea officinalis*).

The genus *Gossypium* to which cotton belongs, contains a number of species, but it is difficult to say just how many. Some authorities include many different varieties and forms under a few species, while others draw the species lines closer. Linnaeus is credited with five or six species; de Candolle recognized thirteen; Parlatore, an Italian who studied the genus about 1866, listed seven species ("Le Specie dei Cotoni"). Todaro, another Italian who monographed the genus, recognized fifty-four species ("Relazione sulla Culta dei Cotoni," 1877-1878). Watt,<sup>1</sup> who has made an extended study of the cottons grown in India and other countries and has studied herbarium specimens from all parts of the world, classifies all the well-known forms, both cultivated and wild, into twenty-nine species and sixteen botanical varieties.

**Species of *Gossypium* Difficult to Classify.**—The genus *Gossypium* is generally considered a difficult one taxonomically. This is not due to the lack of distinguishing marks on the plants, but to several other causes: (1) The foundation laid by Linnaeus was faulty in that he based descriptions of some of the most important species on cultivated plants. (2) Linnaeus' descriptions were not full enough to define species clearly. (3) A large part of the tropics, where wild cotton plants are found most abundantly, has not been explored thoroughly by botanists. (4) For centuries cotton plants have been transferred from country to country for commercial planting. Some of these have

escaped from cultivation, and it is now difficult to determine the original home of certain species or to get any insight into botanical relationship through geographical location. (5) There has been crossing and hybridizing due to the planting of different species and varieties in proximity.

Many species of *Gossypium* may be crossed by insects carrying pollen from one plant to another. It is doubtful if there are many of the American Upland varieties that are not hybrids or blends. As evidence of hybridization may be noted the lack of stability in nearly all varieties and frequent reverersions to unlike, perhaps ancestral, types. In almost every variety specimens with brown lint or floss occasionally appear. Brown is the usual color of the lint of wild species and of some cultivated cottons. Okra-leaved cottons, with leaves resembling those of some of the Asiatic cotton varieties, are of common occurrence. Plants with seeds lacking fuzz, as are found in cottons of the Sea Island type, often appear among plants of fuzzy-seeded varieties. In nearly every variety some plants are found that are off type in length of lint, or lint percentage, shape of boll, size of boll, color of fuzz on seeds, color of stamens, color of petals, habit of branching, size of plant, or in respect to some particular characters.

Some of the above-mentioned off-type forms may be due to mutations, but it is probable that most of them are hybrids reverting to ancestral forms, since it is known that several species hybridize readily and that there has been abundant opportunity for them to do so.

It is therefore impossible to trace out definitely the origin of many of the cultivated species, or, in some cases, even to give with a certainty the land of their origin.

**The Malvaceæ.**—Small<sup>2</sup> characterizes the Malvaceæ, or Mallow family, as follows:

Herbs, shrubs, or rarely trees, of great economic importance, the vegetative parts destitute of any unwholesome substance. Foliage often pubescent with simple or branching hairs. Leaves alternate, stipulate, blades palmately nerved and often lobed, usually crenate or toothed. Inflorescence axillary, racemose, paniculate or corymbose, sometimes congested. Flowers regular, perfect, often subtended by an involucre resembling a second calyx. Calyx of five more or less united sepals; these valvate, mostly persistent. Corolla of five hypogenous convolute petals, alternate with the sepals, united; blades often inequilateral.

Androecium of numerous stamens. Filaments monadelphous, united with the claws of the petals. Anthers reniform, one-celled. Pollen grains hispid. Gynoecium of several carpels. Ovary several-celled, or the several pistils distinct. Styles terminal. Stigmas capitate. Ovules amphitropous or semianatropous, pendulous or ascending, inserted on the inner angles of the cavities. Fruit capsular, or the carpels separate or separable. Seeds solitary or numerous, with a crustaceous, smooth or rough, sometimes pubescent testa. Endosperm scant, fleshy, mucilaginous. Embryo large, curved, or folded, with foliaceous cotyledons.

The Malvaceæ contain 39 genera and some 300 species.

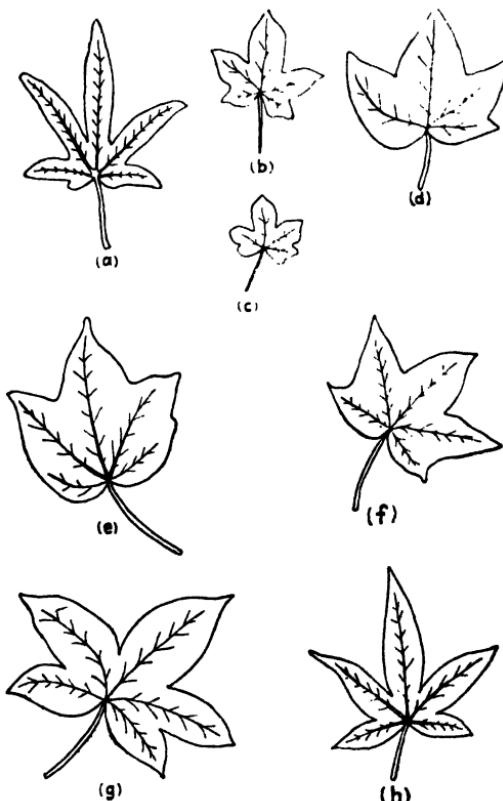


FIG. 1.—Typical leaves of the most important species of *Gossypium*: (a) *G. arboreum*; (b) *G. nanking*; (c) *G. herbaceum*; (d) *G. hirsutum*; (e) *G. purpurascens*; (f) *G. brasiliense*; (g) *G. peruvianum*; (h) *G. barbadense*.

**Gossypium**, of Linnæus.—The genus *Gossypium* may be described as follows: Annual or perennial herbs, shrubs or trees with erect branching stems. Leaves alternate; blades usually

palmately lobed, three to nine lobes, rarely entire; petioled. Involucel of three large, cordate-toothed or incised bracteoles. Flowers rather large and showy, borne singly. Calyx truncate or shortly five-toothed. Petals five, white, yellow, deep red, or purplish; some with purple spot on claw; the white or cream-colored petals become pink or reddish 12 to 30 hours after the flowers open. Ovary three- to five-celled, sessile; styles united into a three- to five-grooved column; ovules one to several in each cell. Fruit a loculicidal capsule with three to five leathery valves. Seeds subglobose to angular pyriform, usually clothed with a coating of long hairs, the floss or lint, and a dense covering of short hairs, the fuzz. The fuzz is lacking in a number of species.

**Species Descriptions.\***—The species described below have the most important cultivated varieties. Purely wild species are not described. Sir George Watt, of England, has made an extended study of the *Gossypium* of the world and collected a large amount of data concerning their species and in his monograph<sup>1</sup> are to be found descriptions of both wild and cultivated species.

#### KEY TO THE CULTIVATED SPECIES OF *GOSSYPIUM*

- A. Seeds without fuzz
- B. Seeds of each loculus united
  - South American species.....*G. brasiliense*
- BB. Seeds of loculus separate
  - C. Leaves small, mostly three-lobed,  
            twigs angled, flowers small  
            Mostly an insular species.....*G. purpurascens*
  - CC. Leaves large, deeply cut into mostly five lobes, twigs round

\* There is much confusion concerning the species of the genus *Gossypium*. Although considerable study has been devoted to them, the information is still unsatisfactory. Authorities do not agree. In order to get the matter cleared up, it will be necessary to make a world-wide study of types now growing, study herbarium specimens, grow various types in culture, and try hybridizing different species.

- D. Fuzz rufous, fruit three- to four-celled, flowers rather large and yellow
  - An Asiatic species ..... *G. nanking*
- DD. Fuzz grayish, fruit four- to five-celled, flowers rather small, yellow.
  - Largely an Asiatic species ..... *G. herbaceum*
- CC. Bracteoles not united below, leaves usually much longer than broad, lobes not obovate nor orbcordate
  - D. Perennial plants, leaves deeply lobed, flowers large, sulphur yellow, fruit three-celled
    - A South American species ..... *G. peruvianum*
  - DD. Annual plants, leaves not deeply lobed, flowers medium-sized, pale yellow, fruit four- to five-celled.
    - A cosmopolitan species grown largely in America. . . . *G. hirsutum*

**Gossypium barbadense**, Linnaeus.—(*G. ritifolium*, Lamarek, and *G. maritimum*, Todaro, are here considered as belonging to



FIG. 2.—Young plants of *G. barbadense* grown on James Island, S. C. (Courtesy C. B. Doyle, U. S. Department Agriculture.)

the species *G. barbadense*, L. Several other forms have been referred to this species by various authors.) Sea Island Cotton.

Shrubby perennial, an annual in cultivation, 4 to 8 feet high, glabrous, dotted with rather prominent black glands. Stem erect, round, and smooth; branches wide-spreading (Fig. 2). Leaves large, deeply segmented into three to five oblong, acuminate, spreading lobes, the central one not much larger than the larger laterals; stipules linear, ovate, acute, oblique; petiole nearly as long as the leaf (Fig. 1g). Inflorescence solitary on an axillary leafy shoot; bracteoles rather large, erect, segments spreading at the top, not deeply cut; bracteoles attached to

calyx tube, slightly united or entirely free; corolla of medium size, usually less than twice the length of the bracteoles, but sometimes larger, petals pale yellow with purple claw. Calyx wide campanulate with large rounded teeth. Fruit an ovate-acuminate capsule, usually three-valved, valves not reflexed; seeds, six to nine in each cell, ovate, beaked, nearly naked; lint fine creamy white, long and silky. Fibers sometimes attain a length of  $2\frac{1}{2}$  inches, but are commonly not longer than  $1\frac{1}{2}$  inches.

*Gossypium barbadense* is a species that has given students of *Gossypium* considerable trouble. It has been a difficult matter to delimit its forms and to trace out their origin and distribution. Watt<sup>1</sup> considers that *G. barbadense*, Hook and Arn. and Parl. (in part) is equivalent to *G. vitifolium*, Lamk., and that *G. barbadense*, Hook, and Benth. is equivalent to *G. punctatum*, Sch. and Thon. *G. barbadense*, Parl. (in part) is described by Watt as *G. barbadense*, L. var. *maritima*, Watt.

*Origin and Distribution.*—*Gossypium barbadense* has by many been regarded as a native of the West Indies, especially Barbados, but Watt<sup>1</sup> in recent studies found but little evidence to substantiate this belief. He thinks that this species may have been cultivated in that region some centuries ago, but that the present Sea Island stock is an improved race, probably developed from a hybrid of *G. barbadense* and *G. brasiliense*. This he designates as *G. barbadense*, Linn. var. *maritima*, Watt.

*Sea Island cotton* is grown in the West Indies, and was cultivated rather extensively in eastern South Carolina, Georgia, and northeastern Florida, and on islands adjacent to those states, until about 1920, when the boll weevil made its culture unprofitable. It has been tried in India, in Egypt, and in other parts of Africa and Australia, and on various islands in the Pacific Ocean, but found to be unsuited to all these regions except the islands. The species is not known in a wild state.

*Important Cottons Derived from Gossypium barbadense.*—In addition to the splendid strains of Sea Island cotton which have been mentioned, several other valuable cottons have been developed from or probably inherit characteristics from *G. barbadense*. The American long-staple upland cottons appear to have some Sea Island traits, and some of the Egyptian varieties resemble Sea Island cotton in various ways.

***Gossypium purpurascens* Poiret (Synonym, *G. racemosum*, Todaro).**—Bourbon, Porto Rico, or Siam cotton.

Perennial shrub or small tree; twigs angled, and glabrous or nearly so. Leaves small, three-lobed, the laterals pointing outward and upward; petiole usually longer than the blade; stipules prominent, ovate oblique linear (Fig. 1e). Inflorescence consists of leafy lateral shoots bearing one or more flowers; bracteoles free or nearly so, ovate, acute, deeply auricled, with seven to nine long linear teeth; flowers small, yellow, often purple spot on claw of petals; calyx wide, campanulate, crenately or dentately toothed. Fruit oblong acuminate, three- to four-celled; seeds ovate, acute, not angled, with rusty fuzz around beak, otherwise smooth and naked; lint white, soft, silky, and easily removed.

*Distribution.*—*Gossypium purpurascens* is possibly only a cultivated form of *G. taitense*, Parl. which it resembles rather closely. It is known only in cultivation and is found widely distributed on islands in the Atlantic, Indian, and Pacific oceans. It has been grown in Upper Egypt, East Africa, Madagascar, Siam, South India, South America, and in other regions.

***Gossypium brasiliense***, Macfayden. (Synonym, *G. conglobatum*, Wiesner).—Kidney, Brazilian, or Pernambuco cotton.

Perennial shrub or small tree. Stem and twigs angular above, rounded below. Leaves large, three to five palmately lobed nearly glabrous (Fig. 1f). Inflorescence, on axillary shoots one- to five-flowered; bracteoles large, cordate, auricled slightly, united below. Glands on upper part of pedicel and inside bracteoles; flowers large, petals pale yellow with orange or red spot on claw. Calyx large, cup-shaped, truncate, or irregularly four- to five-toothed. Fruit oblong, acuminate, beaked, when mature embraced by a large accrescent calyx and bracteoles, three-celled, dehiscing a little more than half its length, valves erect, the margins and beak rigidly reflexed. Seeds of each lock united in a fairly compact mass, medium large, many more or less flattened or angled on account of compression in the lock; naked except a little fuzz at apex; lint abundant, white, fine and silky, but fibers largely lack the twist found in most other cottons; length of staple 1 to  $1\frac{1}{2}$  inches. Yield of lint per acre, poor.

*Distribution.*—*Gossypium brasiliense* is generally regarded as being indigenous to Brazil and other parts of South America. It has been found growing wild in West Africa, and either wild or under cultivation in China, Japan, India, Central America, and the West Indies.

*Important Cottons Derived from G. brasiliense*.—Watt<sup>1</sup> considers that Jumel's cotton, introduced in Egypt in 1820, was probably *G. brasiliense*, and consequently that the present-day Egyptian cotton has this species as one of its ancestors.

***Gossypium hirsutum***, Linnæus. (Synonyms, *G. latifolium*, Murray; *G. barbadense*, Wight; *G. herbaceum*, Small; and others).—Upland, Saw-ginned Dharwar, New Orleans, and Georgia cotton.



FIG. 3.—*Gossypium hirsutum*.

Annual plants, 2 to 4 feet high; lower branches ascending, upper spreading; older parts of stem and branches smooth, younger covered with moderately stiff, spreading, whitish hairs (Fig. 3). Leaves subcordaceous, pale to dark green, varying much in shape, ovate or ovate-cordate, entire, or more commonly three to five shallow, triangular, acute lobes (Fig. 1d); stipules lanceolate, falcate, about  $\frac{1}{2}$  inch long; bracteoles rounded, upper half of the margins with about ten falcately lanceolate acuminate teeth. Flowers varied in size; calyx campanulate, accrescent, with five triangular lobes; petals pale to deep yellow, some forms with purple spot on claws; filaments rather long, allowing the anthers to droop; stigmas long, mostly consolidated

and twisted but occasionally branched at the apex. Fruit is usually four- to five-celled, spherical, ovate, short to long-pointed; valves usually wide-spreading or reflexed; seeds mostly large, ovate, pointed at attachment end, and covered with a dense coating of grayish, rusty, or green fuzz; lint abundant and medium fine to medium coarse, firmly attached to seeds.

*Distribution.*—*Gossypium hirsutum* is not known wild, but it is widely distributed in cultivation. It is to be found all over the American Cotton Belt, and has been collected in Africa, India, Java, China, Persia, and Europe.

*Origin.*—The origin and ancestry of *G. hirsutum* are uncertain. Watt<sup>1</sup> considers the species a cultivated form of *G. punctatum*, Sch. and Thon. That species closely resembles *G. hirsutum*, is well known in a wild state, and has been identified in many regions in which the latter species grows.

*Important Cultivated Cottons Belonging to G. hirsutum.*—The number of cultivated cottons considered as arising from *G. hirsutum* depends, of course, on the conception of species. In the foregoing description the forms belonging to *G. mexicanum*, Todaro, as viewed by Watt, are included. Viewed in this light, very nearly all of the American Upland varieties, certain Mexican varieties, Dharwar cotton in India, Hindi cotton in Egypt, and American varieties in China and in different parts of Africa belong to the species.

***Gossypium hirsutum***, Linnæus, var. ***religiosa***, Watt. (Synonym *G. religiosum* of Linnæus and others).—Nanking. Khaki, or sacred cotton. The true sacred cotton of early writers is probably *G. arboreum* or some one of its varieties grown in southern Asia. Linnæus, however, named as *G. religiosum* a type which is very similar to *G. hirsutum*. This is made a variety of *G. hirsutum* by Watt.<sup>1</sup> It differs from typical *G. hirsutum* in having slender trailing branches, rust-colored fuzz, and usually rust-colored lint.

***Gossypium peruvianum***, Cavanilles. (Synonym *G. ritifolium*, Roxburgh).—South American, Peruvian, or Andes cotton.

Perennial, bushy, twigs long, flexuous, and strongly angled (Fig. 4). Leaves large, thick, usually densely tomentose below, especially when young, ovate-cordate; leaves entire on lower part of the bush, but three- to five-lobed on the rest, lobes broad oblong, acuminate pointed; stipules very large, broad oblong (Fig. 1h). Inflorescence on elongated leafy shoots with generally

solitary extra axillary flowers; bracteoles with six distinct glands, cordate auriculate, free from each other; nerves of bracteoles numerous, raised, and parallel; flowers sulphur yellow, petals with purple claws; calyx loose, obscurely toothed. Fruit ovate oblong, suddenly acuminate, three-valved, scarcely exceeding the bracteoles; seeds large, free from each other, with a gray, rufous, or green fuzz; lint copious but wiry and harsh.



FIG. 4. *Gossypium peruvianum*. Pima American-Egyptian cotton. Considered as belonging to the species *G. barbadense* by some authorities. (After Kearney.)

**Distribution.**—Watt<sup>1</sup> considers *G. peruvianum* as probably indigenous to the Andes in equatorial regions. It has been found growing in Peru and in other parts of South America in Central America, in Africa, and in other cotton-growing countries. It is thought by some authorities to be one of the ancestors of the modern Egyptian cottons.

**Gossypium herbaceum**, Linnaeus.—Levant, or Arabian cotton. Annual, herbaceous, 2 to 5 feet high; stem and branches rounded, slightly zigzag due to bending at joints, somewhat hairy when young but nearly glabrous when mature (Fig. 5). Leaves leathery, glabrous when mature, or nearly so, cordate to sub-

reniform in outline, five to seven lobes, the three middle ones obovate and short-pointed; petiole very long, stipules awl-shaped (Fig. 1c). Pedicels usually shorter than bracteoles; bracteoles large, green, slightly united at the base; flowers hardly twice the length of the bracteoles, rather small, yellow, with purple claws; calyx large, loose about the ovary, with



FIG. 5.—*Gossypium herbaceum*. Grown at Agricultural School, Wuhn, China, 1923. (Courtesy R. R. Childs, University of Georgia.)

short, rounded teeth. Fruit ovoid, beaked, four- to five-celled; seeds large, angled, with gray fuzz and coarse grayish-white lint.

*Distribution.*—*Gossypium herbaceum* is widely grown in Asia and was formerly grown in Southern Europe. It is probably a native of Arabia and Asia Minor. Some authorities consider this the first species of herbaceous cotton grown. It is said to have been taken to America during early colonial days and grown more extensively than any other cotton, but was later displaced by other species.

**Important Cottons Derived from *G. herbaceum*.**—This species is the parent of many Asiatic varieties of cotton. Although many of them are not choice ones, they are grown extensively. The Levant cotton, grown in Arabia, Asia Minor, and southern Europe, is one of the most important. Gammie<sup>3</sup> traces Broach and several other Indian varieties to this species.

***Gossypium nanking*, Meyen.** (Synonym, *G. indicum*, Lamark, and others; *G. herbaceum*, Roxburgh, and others; probably classified by most authorities as *G. herbaceum*).—Chinese or Siam cotton. Watt<sup>1</sup> considers the strain with rufous-colored lint the “Nanking” or “Nankeen” cotton.

Annual or perennial, rather delicate, sparsely branched plant, stems and leaves somewhat hairy; leaf segments extending to middle of the leaf, three to five lobes, larger ones constricted somewhat below, bluntly acute to acuminate at apex; two lower lobes appear to be an extra addition to leaf (Fig. 1b). Bracteoles are large, purplish, united below, with three to four sharp teeth on the apex. Flowers rather large, yellow; petals with faint-purple claws. Fruit somewhat angled, three- to four-celled; seeds large, irregular, covered with dense coating of rufous fuzz; lint white, tending to become rufous.

**Distribution.**—*Gossypium nanking* is not known wild, but, as determined by Watt,<sup>1</sup> is cultivated in China, Japan, Malaya, Siam, Burma, India, Central Asia, Arabia, Madagascar, and Africa.

**Important Varieties.**—A large part of the native cultivated cottons of China and Japan belong to *G. nanking*, as probably do many of the cultivated varieties in India and other parts of Asia.

***Gossypium arboreum*, Linnaeus.** (Synonyms *Xylon arboreum*, Boerhaave, *G. rubrum*, Forskal).—Tree cotton of India and Africa, Deo, or Nurma cotton.

Perennial, 6 to 10 feet high; branches long and slender; young branches and petioles purple (Fig. 6). Leaves thick, leathery, smooth, cordate, deeply segmented into five to seven oblong lanceolate lobes; often a secondary lobe within the lateral sinuses (Fig. 1a). Bracteoles comparatively small, united below, ovate-cordate, entire or occasionally toothed. Flower large, white to purple with darker spots on petals. Fruit rounded with flattened sides, three- to four-celled, valves with margins reflexed; seeds rather large, coated with grayish-green fuzz; lint white in cultivated forms, rufous in wild.

*Distribution.*—*Gossypium arboreum* is not known in its original wild state. It was probably the first species cultivated and was observed in cultivation in India, Arabia, and Africa centuries ago. It is now found in gardens in India, Arabia, Indo-China, Japan, Java, and Malaya.

*Cultivated Races.*—Although the typical *G. arboreum* is at present cultivated as a field crop but very little, if at all, several



FIG. 6.—*Gossypium arboreum*. (After Leake.)

races from its numerous varieties are of importance for field planting. Bengal, Jari, Deshi, Dacca, and the Garo Hill cotton may be mentioned.

**Wild Species.**—In Mexico, Lower California, Arizona, Central America, Brazil, Africa, Australia, on islands in the Pacific Ocean, and perhaps in other parts of the tropics are wild species of cotton. Most of these that have been described are named in the following list. Some few of the number are cultivated to a limited extent, but are not of much economic importance.

WILD SPECIES	RANGE
<i>G. Davidsonii</i> , Kellogg.....	Lower California
<i>G. Klotschianum</i> , Anderson.....	Galápagos Islands
<i>G. Darwinii</i> , Watt.....	Galápagos Islands
<i>G. tomentosum</i> , Nuttall.....	Hawaiian Islands
<i>G. Harknessii</i> , Brandegee.....	Lower California
<i>G. Stocksis</i> , M. Mast.....	India
<i>G. obtusifolium</i> , Roxburgh.....	India and East Indies
<i>G. mustelinum</i> , Miers.....	Brazil and Colombia
<i>G. punctatum</i> , Schumacher and Thonning.....	United States, Mexico, and West Indies
<i>G. palmerii</i> , Watt.....	Mexico
<i>G. fruticosum</i> , Todaro.....	Mexico
<i>G. Schottii</i> , Watt.....	Yucatan
<i>G. lanceolatum</i> , Todaro.....	Mexico
<i>G. microcarpum</i> , Todaro.....	Mexico, South America, and Africa
<i>G. taitense</i> , Parlatore.....	Polynesia
<i>G. Kirkii</i> , M. Mast.....	Africa
<i>G. mexicanum</i> , Todaro.....	Mexico
<i>G. Hopi</i> , Lewton.....	Arizona

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## CHAPTER III

### CULTIVATED VARIETIES OF COTTON

The term "variety" is used in this chapter in the sense in which the cotton grower uses it and not in the botanical sense. Varieties that the botanist knows are divisions of or offshoots from species. They differ from the regular species by one or more, perhaps slight but definite and permanent, hereditary characters. The planter's varieties are not distinguishable by such definite or permanent marks, although the apparent differences may be much more striking, as, for instance, the difference between Triumph, a big-bolled, low, vigorous-growing, large-leaved, short-staple variety, and Express, a small-bolled, tall-growing variety, with small leaves and long staple. Divisions of agricultural varieties are known as "strains." The plants belonging to a strain differ from others of the variety by one or more more or less well-marked characteristics. The agricultural varieties are not entirely uniform, and do not breed true to type in all cases. Genetically considered, they are of hybrid constitution; various reversions and combinations of ancestral characters appear. Consequently, many different forms arise. W. A. Cook, a cotton breeder at Newman, Mass., noticed this 30 years ago. He said:

I can take any of the so-called distinct varieties of cotton and in a few years develop all the known varieties from it. In other words, they will develop themselves in the course of time. All that is necessary is to watch the field from year to year, and when a "sport" is noticed, to save the seeds and plant them by themselves.

Probably Cook's idea of a "sport" was a little different from ours, but it may be understood that he meant that many new forms appear in cotton fields. This is known to be a fact. Dr. R. Y. Winters, of the North Carolina Experiment Station, has recently verified Cook's conclusions by actual experiments. He made selections from a commercial variety, King, for a series of years. From this one variety he obtained both long-staple and short-staple strains, and other strains differing in size and

shape of boll, lint percentage, habit of growth, etc. This unstable condition of cotton varieties has come about from promiscuous mixing and crossing. Mutations probably occur occasionally. The mutants and different varieties and strains brought in from other parts of the Cotton Belt or from foreign countries when planted near local varieties, hybridize with them frequently. These hybrids cross with other plants, the new ones with still others, and so on, the final result being a hybrid complex unless selections are made and careful breeding work is carried on. Comparatively, very little breeding work was done prior to 1900.

**Number of Cotton Varieties.**—No one can determine just how many varieties there are in any cotton-growing country, but the number is large. Every country—in fact, almost every community—has its local varieties. Most of these so-called varieties, however, are simply duplicates of a comparatively small number of well-defined varieties. In Mississippi there are not more than twenty distinct varieties, and in the whole Cotton Belt probably not more than thirty. Each foreign country has a limited number of varieties peculiar to its territory.

This multiplicity of varietal names has come about in different ways. If a planter gets seed of a certain variety, and it does well, he will continue to grow it for some years. His neighbors, seeing the good cotton, will purchase some of the seed. When they speak of the cotton they are growing, they are apt to give it the name of the man from whom they secured the seed. Thus, after a few years, there is a new varietal name. Sometimes new names are given old standard varieties by unscrupulous seed dealers in order to sell seed to a better advantage. New variety names are also originated by breeders for their new productions. This practice is entirely proper if the new strain differs from the old by sufficient marks to make it worthy of a distinct name.

The U. S. Department of Agriculture should have a bureau for the registration of legitimate varieties of all agricultural crops. The registration requirements should be such that they would eliminate illegitimate varieties of cotton and secure credit to breeders who have labored to produce new varieties of merit.

**Origin of True Varieties.**—As has been mentioned, the cotton plants in a field vary considerably. New forms are frequently appearing, because of the segregation and recombination of characters in hybrid strains, because of mutations, and because

of climatic adjustments. When a strain is grown in a district for a period of time, the plants best adapted to the prevailing conditions produce the most fruit, and consequently have the largest progenies. There is a natural adjustment, or a survival of the fittest. When this natural adjustment is aided by the intelligence of the breeder, desirable and well-adapted varieties may be secured.

The life of a variety is of rather short duration. Tracy<sup>1</sup> mentions that of the fifty-eight varieties named in the Tenth Census report for 1880, only six were common in cultivation in 1895. These were Boyd Prolific, Dickson, Herlong, Peeler, Petit Gulf, and Texas Stormproof. None of these are grown to any extent at present, and most of them are extinct.

Of the 118 varieties listed by Tracy<sup>1</sup> in 1895, only 2, King and Truitt, are in common cultivation today. Tyler,<sup>2</sup> in 1907, listed nearly 400 varieties. Of this number not more than 25 varieties are in existence at present, and only 9 of these are cultivated extensively.

**Botanical Species Represented in the United States.**-- According to the general consensus of opinion of students of the subjects, three or more species of *Gossypium* are represented in the cultivated varieties in the United States. These are *G. barbadense*, L., with Sea Island as its only representative; *G. peruvianum*, Cav., with the Egyptian varieties grown in the Southwest as representatives; (the Egyptian varieties are often considered as belonging to the species *G. barbadense*); *G. hirsutum*, L., represented by various Upland varieties. As has been mentioned before, most American varieties are the product of repeated hybridization and consequently few, if any, pure botanical species are to be found among the cultivated varieties. Certain characteristics of a species may be noticed in a variety and a conjecture made that that species is one of its ancestors. Watt considers that several other species and botanical varieties belong in the ancestry of American Agricultural varieties, among which may be mentioned *G. arboreum neglectum*, Watt; *G. herbaceum*, L., *G. punctatum jamaicum*, Watt., *G. purpurascens*, Poir., and *G. Schottii*, Watt. It is very probable that other species in addition to the three first mentioned above have entered into the composition of American varieties, since cottons have been imported from every section of the cotton-growing world and grown alongside the established varieties. There has been

abundant opportunity for hybridization to take place (see Chap. II for further discussion of species).

**Relative Value of Varieties.**—The relative value of a variety varies greatly with the season, market conditions, and adaptation to the environmental conditions where grown. The weather and market conditions that are to prevail cannot be foretold; consequently, there is no way of selecting in advance the variety that will be best suited for any particular locality. But the environmental factors of a locality are more or less permanent and fixed, and it is possible to make some varietal selections on the basis of average conditions. Boll weevils are worse in some places than in others. An early prolific variety is of most value in such regions. Some lands are less fertile than others; a hardy, vigorous-growing strain yields best on such lands. Rainfall and other factors also vary. It is, of course, most profitable to grow the variety best suited to meet all conditions. The safest and surest way of determining values for any plantation is to make tests on the place. Reliable information may be obtained if different varieties are grown side by side, under the same conditions, and comparisons are made.

**Classes of Varieties.**—Duggar<sup>3</sup> groups the Upland varieties in eight classes: the Cluster, or Dickson type; Semicluster, or Peerless type; Rio Grande, or Peterkin type; King-like, or King type; Big-boll, or Truitt type; Long-limb, or Petit Gulf type; Intermediate, various types; and Long-staple Upland, or Allen type.

Duggar's system of classification is a good one in that an effort is made to group the various varieties according to their natural relationship, and various characters are considered. This system was very generally adopted and used for a number of years. With the passage of time certain of the varietal types have been lost because some varieties have become extinct. Also some important new varieties which combine characters belonging to more than one of the old groups have arisen through hybridization or otherwise. These changes in varieties have made the Duggar system of classification less satisfactory than formerly.

The system proposed below is more or less artificial in that it is based on but few plant characters, principally boll size and staple length, but it is believed that it will be helpful in classing or grouping the varieties now grown.

Group 1. King type—early, small-boll, short-staple group.  
 Group 2. Dixie type—medium-late, small-boll, short-staple group.  
 Group 3. Cook type—round-boll, short-staple group.  
 Group 4. Triumph type—big-boll, medium staple group.  
 Group 5. Delfos-6102 type—small-boll, long-staple group.  
 Group 6. Webber type—big-boll, long-staple group.  
 Group 7. Various types—mixed or intermediate group.

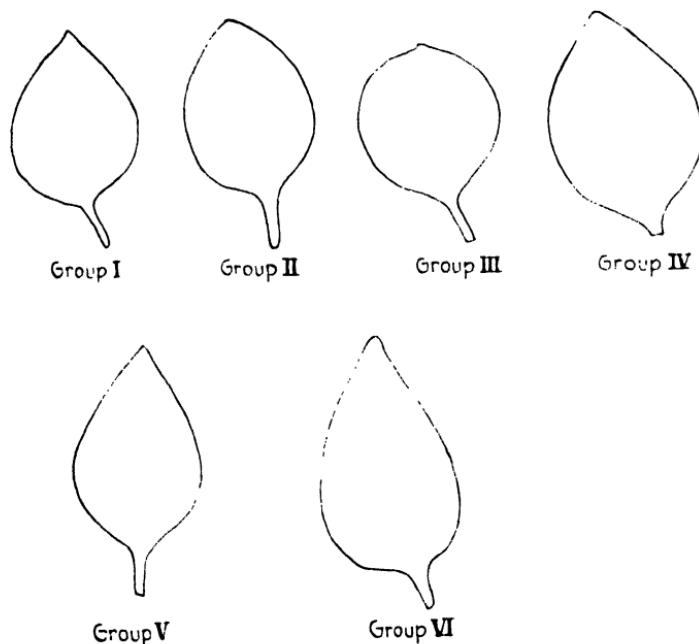


FIG. 7. An outline sketch of a typical boll from each of the groups of Upland varieties.

**Early, Small-boll, Short-staple Group.\***—The varieties in this group are characterized by their earliness, numerous small bolls, and short staple. Correlated with the earliness are several other characters which make the division fairly well defined. The plants are slender, mostly rather low, usually with one to three slender spreading basal vegetative branches; leaves small to

\* In this classification, staple from the shortest to 1 inch in length is considered short staple;  $1\frac{1}{2}$  to  $1\frac{3}{4}$  inch, medium-length staple; and  $1\frac{1}{4}$  inch and longer, long staple. Bolls requiring fewer than seventy to make a pound of seed cotton are considered big bolls; bolls requiring seventy or more, small bolls.

medium size, softly hairy, with lobes narrower and deeper than those of the big-boll cottons; bolls small (see Fig. 7) three- to five- but mostly four-locked; lint short and of good strength; seeds small to medium size, fuzzy, and greenish to brownish gray.

King, a common variety at the present time, is a good illustration of the group. There are also a number of selections either from King or its ancestor, Sugar-loaf, also in common cultivation (see Fig. 8).

**Medium-late, Small-boll, Short-staple Group.**—The varieties within this group are medium late and only medium prolific

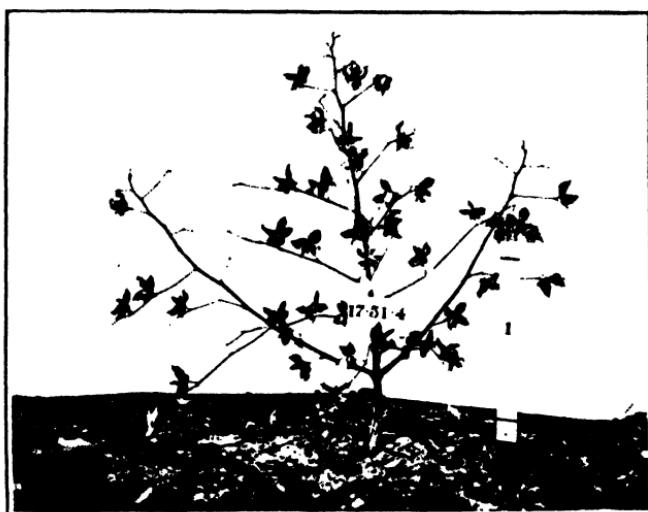


FIG. 8.—Plant of the King variety illustrative of the early, small-boll, short-staple group. (Courtesy R. Y. Winters.)

but they are healthy and of vigorous vegetative growth. The group contains important wilt-resistant varieties, of which Dixie may be taken as a type (see Fig. 9). The plants are rather tall and slender with one to several long, slender, ascending to erect, basal vegetative branches; fruiting branches are slender and usually long-jointed; leaves small to medium in size, rather hairy when young, with lobes narrower and deeper than those of the big-boll, medium-staple group; bolls small to very small in size, with three, four, or five locks, the locks remaining rather compact and firm for some time after the boll opens; lint medium short, of good strength, wiry, and elastic; lint percentage usually high, 35 or above; seeds, small to very small, some nearly smooth

and brownish black, but the majority covered with a short, sparse fuzz.

**Round-boll, Short-staple Group.**—The varieties in this group are characterized by a medium-sized, rounded boll, short staple, and high lint percentage. The plants are medium early, of medium size, vigorous in growth, and range from semicompact to somewhat spreading in habit. Leaves are medium to rather



FIG. 9.—Plant of the Dixie variety illustrative of the medium-late, small-boll short-staple group. (Courtesy R. Y. Winters.)

large. Bolls rounded, sixty to seventy to a pound, mostly four-locked; lint per cent, 35 to 42; staple length,  $3\frac{1}{4}$  to 1 inch; seeds medium in size with fuzz of various colors.

Cook and Wannamaker Cleveland are good illustrations of the round-boll, short-staple group. They are cultivated extensively at present.

**Big-boll, Medium-staple Group.**—The main characteristic of this group is the large size of the boll, which is measured by the

weight of the seed cotton within the boll. When plants are grown under normal conditions, this ranges from about forty bolls to the pound for the largest bolls to about seventy for the smallest. The plants of the group are stocky, usually vigorous; the basal limbs strong and heavy, rather short, and two to three in number if the plants are not crowded. Fruiting branches are strong, ranging from very short and irregularly jointed or semiclustered to very long-jointed; leaves, large; bolls with four to five locks; seeds, mostly large, fuzzy, of various colors; lint, medium length,



FIG. 10.—Plant of the Rowden variety illustrative of the big-boll, medium-staple group. (After Tyler.)

mostly  $11\frac{1}{2}$  inches, soft and of good strength; lint per cent, 31 to 38, usually 35 or above (see Fig. 10).

Certain varieties belonging to the big-boll, medium-staple group have been selected in Texas for storm resistance. These are sometimes designated as the stormproof group. They are very sturdy and vigorous in growth, and the bolls mostly hang downward, so that the spreading burs form a sort of roof over them to shed off falling water. The locks are held in the boll securely, but, being rather firm and protruding well, are easily picked.

Triumph, Long Star, and Rowden are good illustrations of the big-boll, medium-staple group.

**Small-boll, Long-staple Group.**—This group is characterized by the length and character of the lint and the small bolls belonging to its members. Many varieties have a number of characters that are correlated more or less with the staple characters but, the group also includes some varied forms. The majority of the older varieties were late, but recent ones are early. Most of the varieties have plants rather tall and slender, with two or three slender, upright basal vegetative branches, and long, slender fruit branches with joints of various lengths. The foliage is somewhat sparse; leaves small to medium in size, with



FIG. 11.—Plant of the Delfos-6102 variety illustrative of the small-boll, long-staple group. This plant was grown under more favorable conditions than the others shown and consequently has more bolls.

narrow lobes; peduncles often long and slender; bolls small to medium in size, with three, four, or occasionally five locks; the cotton of each holds together in a rather loose mass; lint,  $1\frac{1}{8}$  to  $1\frac{3}{8}$  inches in length, weak to moderately strong, very soft, fine, and clinging, the best types resembling the lint of Sea Island cotton; seeds small to medium in size, sometimes naked or partly naked, but usually covered with a brownish-gray or gray fuzz. The habit of growth, the lint characters, and the yellow pollen of many varieties within this group indicate relationship to Sea Island cotton. It is known that some of the varieties contain Sea Island "blood" and very probably many of them do (see Fig. 11).



FIG. 12. - Plant of the Delta-type Webber variety which belongs to the big-boll, long-staple group. (Courtesy George J. Wilds.)

**Big-boll, Long-staple Group.**—This group comprises principally varieties that have been produced comparatively recently by combining characters in one variety which were formerly found in different varieties, as, for instance, big boll and long staple. The varieties in this group are medium early, and only medium in respect to prolificness. The plants are rather compact, stocky, short-limbed, and, in general, resemble the big-boll, medium-staple varieties in vegetative characters. The bolls are mostly more or less long-pointed and before opening appear to be very large, but the amount of seed cotton contained is not in proportion to the apparent size of the boll. The bolls are four- and five-locked and sixty to seventy are required to make a pound of seed cotton. Seeds are of medium size, and covered with fuzz; per cent of lint, 30 to 32; lint length,  $1\frac{3}{16}$  to  $1\frac{3}{8}$  inches; lint soft and silky and usually of excellent character.

Deltatype Webber and Delfos-631, varieties cultivated extensively at present, are good illustrations of the big-boll, long-staple group (see Fig. 12).

**Intermediate Group.**—This group contains varieties which possess one or more important characters which are more or less intermediate between characters of plants of other groups, or they have some definite characters of two or more groups. They can be placed only in a heterogeneous class.

**Leading Cotton Varieties.\***—The following lists have been prepared by the agronomists in the cotton-growing states. Varieties are listed in order of popularity, in general, but in many states this varies in different parts of the state.

\* The Missouri and Mississippi lists were prepared in 1923; the Arkansas, Louisiana, and Oklahoma list in 1925; the North Carolina in 1926; the others in 1921. In some instances new varieties have come in and others have changed in importance since 1921.

TABLE I.—LEADING COTTON VARIETIES GROWN IN U. S.

State	Agronomist	Varieties	Remarks
Virginia.....	T. B. Hutcheson	Trice King Simpkins	No other varieties have shown much promise for this state.
North Carolina.....	R. Y. Winters	Wannamaker Cleveland Mexican Big Boll Dixie-Triumph	Dixie-Triumph recommended only on wilt-infected land.
South Carolina.....	C. P. Blackwell	Cleveland Big Boll Cook Mexican Big Boll College No. 1 Dixie-Triumph Dixie-Cook Dixie Express Deltatype Webber Webber-49	Cleveland is our first choice for wilt-free land. Dixie-Triumph is recommended for wilt-infected soils.
Georgia.....	R. R. Childs	College No. 1 Piedmont Cleveland Wannamaker Cleveland Cook's Improved Texas Bur Covington-Toole Council-Toole Lewis-63 Express Webber	There are other strains of Cleveland that are good. Petty's Toole is another good wilt-resistant variety.
Florida.....	Frazier Rogers	.....	The cotton crop is no longer of importance in Florida. Only the extra-early varieties can be used with any degree of success.
Alabama.....	J. F. Duggar	Cook Cleveland Wannamaker Cleveland Toole Cook Wilt resistant	These varieties are placed in the lead from general impressions rather than from average yields.
Tennessee.....	C. A. Mooers	Express Trice Wilson Improved Big Boll Cleveland Perry Improved Petway	Express is placed first because of its somewhat better lint. Trice is recommended because of its earliness.
Missouri.....	I. P. Trotter	Trice Delfos Express Acala	The varieties listed are recommended. Only early varieties are satisfactory.
Mississippi.....	W. E. Ayres	Cleveland Half and Half Trice Cook Miller Delfos Express Salsbury Deltatype Webber Webber-49	The first five varieties are grown most extensively in the hill section of the state and the last five in the Delta.
Louisiana.....	A. F. Kidder	Half and Half Wannamaker-Cleveland Cleveland Delfos Toole Salsbury Express Rowden Acala	The varieties now grown in the state, in order of acreage, are shown in the accompanying list.
Oklahoma.....	Glen Briggs	Triumph Acala Rowden Lone Star	Some other varieties are grown to a limited extent.

TABLE I.—LEADING COTTON VARIETIES GROWN IN U. S.—(Continued)

State	Agronomist	Varieties	Remarks
Texas.....	A. H. Leidigh	Mebane's Triumph Kusch Lone Star Bennett Rowden Belton Truitt Acala Durango	These varieties are doubtlessly the best varieties in general use in Texas. It is impossible to give them in order of value, because the value varies for different sections of the state.
Arkansas.....	J. H. Moore	Acala Trice Express Delfos Cleveland Triumph Rowden Lone Star	These varieties are recommended for different sections of Arkansas. They seem to be the best ones available at present. Some are adapted to one region and others to another.
New Mexico.....	G. R. Quesenberry	Durango Triumph Lone Star Acala Rowden Webber King	Durango constitutes the largest percentage planted in the state, and Triumph contributes most of the remaining acreage. Cotton is comparatively a new crop.
Arizona.....	W. E. Bryan	Pima (Egyptian) Triumph	Cotton has been grown in the state only a comparatively short time. Only two varieties have attained any importance.
California.....	B. A. Madson	Triumph Durango Pima (Egyptian)	Without figures giving relative amounts of production, I am of the opinion that the Egyptian ranks third.

**Varieties Grown in Different States.**—According to reports made by agronomists in the various cotton-growing states, varieties belonging to the round-boll, short-staple group are grown most extensively, with Cleveland the leader, in states east of the Mississippi River; and to the big-boll, medium-staple group in states west of the river. Triumph is apparently the leading variety in the western states. The wide range of these varieties is due to their adaptation to thin hill lands, which cover a large part of the area of the cotton belt. In Texas they better withstand the hot, dry weather that often prevails there. The large bolls also help make these varieties popular, since they are easier to pick. Where the farmer does his own picking, this is important. In the states at the northern edge of the belt only early varieties are satisfactory. Trice is considered the best variety for Virginia and Tennessee. In the irrigated regions of Arizona and California Durango, Acala, and Pima, the latter an American-Egyptian variety, are favored. In the Delta regions

of Mississippi, Arkansas, and Louisiana early long-staple varieties are grown principally, Delfos and Express being the most popular.

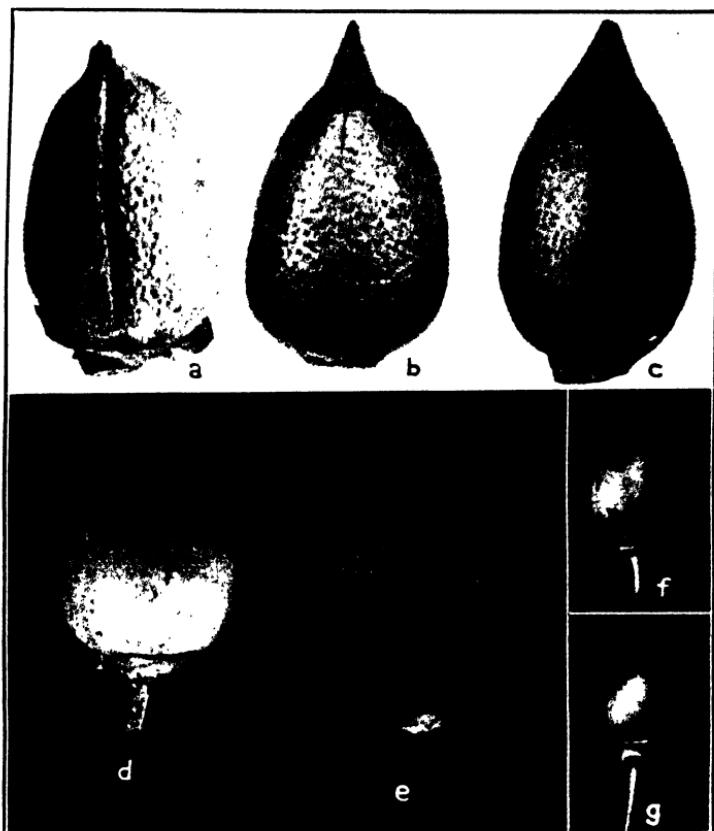


FIG. 13.—Bolls of important types of cotton. *a*. Egyptian Mit Afifi. About natural size. *b*. Egyptian Sakellaridis. About natural size. *c*. American-Egyptian Pima. About natural size. *d*. Upland short staple, Cook variety. Slightly larger than half natural size. *e*. Upland big boll, Lone Star variety. Slightly larger than half natural size. *f*. Upland long staple, Express variety. Somewhat less than half actual size. *g*. American Sea Island. Somewhat less than half actual size.

**Description of Upland Varieties.**—A brief description and history of a number of Upland varieties are given below. This list is not exhaustive. An attempt has been made to include only the most prominent old-time varieties, some varieties from which prominent present-day varieties have sprung, and the leading varieties being grown at present.

*Allen Long Staple* (Small-boll, Long-staple Group).—Developed about 1898 by J. B. Allen, Port Gibson, Miss. At one time this variety was grown extensively through out the Delta of Mississippi and in other long-staple districts, but it is now displaced by earlier long-staple varieties.

Plants are tall and pyramidal in shape; semicluster in habit of growth; with one to three vegetative limbs near the base of stalk and short, irregularly jointed fruiting branches; bolls medium to small; lint very long and silky; seeds medium to small, fuzzy, white; bolls per pound, seventy-eight; seeds per pound, 3,800; length of lint,  $1\frac{3}{8}$  to  $1\frac{9}{16}$  inches; strength of fibers, 4.3 grams; percentage of lint, 29. Adapted from Tyler.<sup>2</sup>

*Acala* (Intermediate Group).—This variety was developed from imported seed obtained by G. N. Collins and C. B. Doyle in 1906, at Acala, in the



FIG. 13a.—Field of Upland cotton at blooming time. A scene in the Mississippi Delta.

state of Chiapas, southern Mexico. The present strain was developed from a selection of twenty plants made by Dr. D. A. Saunders, in 1911, from the original field grown at Waco, Tex. Acala is grown most extensively in Oklahoma, Texas, and western Arkansas.

Plants are of medium height, with strong, erect main stem, few vegetative limbs; fruiting branches short-jointed; lower branches long, upper branches short; leaves of medium size, dark green; bolls of medium size, ovate, with short, blunt points; burs often pendant, stormproof; bolls per pound, fifty to fifty-five; length of lint,  $1\frac{1}{16}$  to  $1\frac{9}{16}$  inches; staple with good drag and extra strong; percentage of lint, 32 to 35. After Oakley.<sup>6</sup>

*Acala No. 5*.—This is an Acala selection made by the Nunn Seed Company, of Porter, Okla. It is grown rather extensively in Oklahoma and Arkansas.

*Bohemian* (Big-boll, Medium-staple Group).—Also known as Supak, Shupark, Shoepeck, Shuparch, etc. Originated over sixty years ago by a

Bohemian settler named Supak, living in Travis, Austin County, Texas. Bohemian was a very popular cotton in Texas at one time, but has been displaced by other varieties. It is the parent of Rowden.

Plants are large, basal limbs two to three, often nearly prostrate; fruiting branches numerous and long, somewhat drooping; joints short and regular, making the plant very prolific; foliage heavy; bolls large, usually turned down by their weight, so that when the boll opens the lint is protected by a roof formed partly by the broad backs of the segments of the bur and partly by the large involucre; picks easily; lint medium length; seeds large, fuzzy, gray or brownish-gray; bolls per pound, fifty-five; seeds per pound, 3,240; average length of lint,  $1\frac{5}{16}$  inch; strength of fiber, 5.3 grams; percentage of lint, 33 to 34. Adapted from Tyler.<sup>2</sup>

*Boykin Stormproof* (Big-boll, Medium-staple Group).—Originated by W. L. Boykin, Kaufman, Kaufman County, Texas. It is not grown extensively at present.

Plants are large and stocky; fruiting branches long and long-jointed, late maturing; bolls large, majority five-locked, holding cotton well during storms, but easily picked as locks cling together in one mass; lint of good length; good percentage of lint; seed large, fuzzy, brownish-gray; bolls per pound, fifty; seed per pound, 3,280; length of lint,  $1\frac{1}{32}$  inches; strength of fiber, 5.2 grams; percentage of lint 34. Adapted from Tyler.<sup>2</sup>

*Brannon* (Intermediate Group).—Brannon was developed from a selection made by G. W. Brannon, Feliciana Parish, Louisiana, and further improved by N. B. Riddle, Riddle, La., a son-in-law of the originator, and by G. Brannon, Lindsay, La. It is intermediate between the Upland long-staple and the Peterkin groups. It is not grown extensively now, if at all.

Plants are tall and slender; basal limbs, one to three or more; fruiting branches long, rather long-jointed; bolls medium to large; seeds of medium size, covered with a short, sparse, brownish-gray fuzz, or nearly naked; bolls per pound, sixty-six; seed per pound, 4,000; length of lint, 1 inch; lint percentage, 32 to 37. Adapted from Tyler.<sup>2</sup>

*Cleveland* (Round-boll, Short-staple Group).—Known also as Cleveland Big Boll. This variety was developed by J. R. Cleveland, Stratton Miss., by 25 years of mass-selection work. The variety came into prominence about 1890. It is not grown extensively at present, having been supplanted largely by strains developed from it, as Wannamaker Cleveland, Piedmont Cleveland, etc.

Plants are not uniform, being both semicluster and open in growth; joints of fruiting branches short, making the variety medium-early maturing; bolls large, 50 per cent five-locked, not stormproof; lint of medium length; seed medium large, fuzzy, light brownish-gray; bolls per pound, about sixty; seeds per pound 3,100; lint length,  $1\frac{5}{16}$  inch; strength of single fibers, 5.5 grams; percentage of lint, 35 to 37.

*Wannamaker Cleveland* (Round-boll, Short-staple Group).—This strain of Cleveland was developed by the plant-to-row method by W. W. Wannamaker and Sons, of Saint Matthews, S.C. The work was first begun in 1908. The variety came into prominence in 1916, the year the seed were placed on the market in a commercial way. It is earlier and more prolific, has smaller bolls, and is a lower-growing and more spreading plant than the

parent variety. It is widely grown in hill-land districts east of the Mississippi River and to some extent in Arkansas and Louisiana.

Plants are of medium height with medium foliage, mostly with three or four basal vegetative limbs; medium early and fairly prolific; bolls rounded with very blunt tip, sixty to sixty-nine to a pound; 35 to 37 per cent lint;  $7\frac{1}{8}$ - to 1-inch staple semiresistant to wilt.

*Cleveland-54* (Round-boll, Short-staple Group).—This is a selection from Wannamaker Cleveland made by the Mississippi Experiment Station. It differs from the parent strain in having rather more compact plants and is slightly earlier and more prolific.

*Piedmont Cleveland* (Round-boll, Short-staple Group).—This is a strain selected from Cleveland Big-Boll by J. O. M. Smith and J. N. Collins, of Commerce, Ga. It resembles the parent strain in habit of plants, but is earlier, more uniform, and more prolific.

*College No. 1* (Round-boll, Short-staple Group).—This is a new short-staple variety that is showing much promise in Georgia; it is a selection from Sunbeam, a hybrid variety from a cross between Cook's Improved and Columbia. It is now grown in Georgia considerably.

Plants are of medium size, with no to one basal vegetative branch; fruiting branches long with medium-length joints, there being no indication of the cluster habit; bolls large, oblong, sixty per pound; length of staple,  $1\frac{5}{16}$  inch; lint percentage, 38.

*Columbia* (Big-boll Long-staple Group).—A selection from Russell made by Dr. H. J. Webber while in charge of Plant Breeding Investigations, U. S. Department of Agriculture. It was grown somewhat extensively for some years in the Delta sections of Mississippi and Arkansas, and also in North Carolina and South Carolina, but recently it has been displaced by Webber and its strains.

Plants are similar to Russell; bolls large, long, ovate; lint not uniform, not silky like Sunflower, but stronger; seed large, fuzzy, gray, a small proportion green; bolls per pound, sixty-six and a half; seed per pound, 3,400; lint length  $1\frac{1}{4}$  inches; strength of single fibers, 5.6 grams; percentage of lint, 31.7. Adapted from Oakley.<sup>6</sup>

*Cook or Cook's Improved* (Round-boll, Short-staple Group).—Originated by J. R. Cook at Ellaville, Ga., in 1895. This is a medium- to large-bolled variety, yielding a high percentage of lint and is medium early. Selections made by the Alabama Experiment Station have displaced the parent strain of Cook to a large extent.

Bolls are quite round, 54 per cent 5-locked; seed medium in size, fuzzy, greenish, or brownish gray; not stormproof and susceptible to boll rot; bolls per pound, sixty to sixty-five; seed per pound, 4,000; length of lint,  $7\frac{1}{8}$  inch; strength of single fibers, 6.8 grams; percentage of lint,  $38\frac{1}{2}$ . Adapted from Tyler.<sup>2</sup>

*Alabama Station Cook*.—This is a strain of Cook developed by the Alabama Station. It differs from the parent variety in having smaller bolls, and higher lint percentage, and is more uniform.

*Tri-Cook or Triumph Cook*.—This variety was developed by M. R. Hall, James, Ala., in 1910, from a selection made in a field in which mixed seed of

Cook and Triumph had been planted. The plants are not uniform; they resemble Cook largely. The strain is more resistant to wilt than Cook, and has given more profitable yields on wilty soils.

*Cook-1010*.—This strain, originated by the Alabama Experiment Station, differs from the Alabama Station Cook in having smaller bolls, sixty-six to seventy per pound; higher lint percentage, 40 to 42, and shorter staple,  $3\frac{3}{4}$  to  $7\frac{1}{8}$  inch. It is a good yielder.

*Cook's Long-staple* (Small-boll, Long-staple Group).—Developed by W. A. Cook, Newman, Miss. This variety is closely related to Allen. It was a popular variety in long-staple districts for several years, but is not grown at present, having been superseded by earlier long-staple varieties.

Plants are tall and pyramidal in shape, with one to three limbs, or often none; fruiting branches showing a tendency to semicluster, but not so short and irregularly jointed as Allen; bolls of medium size, pointed; lint of good length, soft and silky; seeds of medium size, fuzzy, gray; bolls per pound, sixty; seed per pound, 3,650; lint length, 1 to  $1\frac{1}{4}$  inches; strength of single fibers, 4.7 grams; percentage of lint, 28.3. Adapted from Tyler.<sup>2</sup>

*Culpepper* (Intermediate Group).—Developed by L. E. Culpepper, Luthersville, Ga., by mixing seed of Wyche and Dickson. These dissimilar varieties have blended by hybridization into a fairly uniform intermediate cotton, still showing, however, a few plants approaching the parents in character of growth. The cross was made about 1890, and for some years the variety was rather common throughout the Cotton Belt. It is not grown very extensively now.

Plants are semicluster in habit of growth, with one to three basal vegetative limbs, fruiting branches short and irregularly jointed, bolls large, rounded, lint of medium length; percentage good; seeds large, fuzzy, greenish- or brownish-gray in color; bolls per pound, fifty; seed per pound, 3,380; length of lint,  $2\frac{9}{32}$  inch; strength of single fibers, 6.7 grams; percentage of lint, 35.1. Adapted from Tyler.<sup>2</sup>

*Delfos 6102* (Small-boll, Long-staple Group).—This variety sprang from a single outstanding plant selected in a field of Foster-120 at the Mississippi Delta Experiment Station, in 1916, by H. B. Brown. It is grown extensively on alluvial lands in Mississippi, Louisiana, and Arkansas.

Delfos-6102 is very early and very prolific; it has low-spreading open plants, with comparatively slender main stem and branches; the fruiting branches are long and numerous; one to four basal vegetative branches are found on the plant if wide spaced; leaves are small, having a pale-green color; bolls are narrowly ovate, short-pointed, four- and five-locked, open well, pick fairly well, and run seventy to eighty to the pound of seed cotton; percentage of lint, 31 to 32; length of staple,  $1\frac{1}{8}$  to  $1\frac{3}{16}$  inches.

*Delfos-631* (Big-boll, Long-staple Group).—This strain arose from an individual plant selection made at the Mississippi Delta Branch Experiment Station, in 1916, by H. B. Brown. It is grown in much the same region as Delfos-6102, but not so extensively.

Plants are erect, of medium height, and rather open; where plants are not crowded in the drill there are one or more basal vegetative branches; leaves are small to medium size, bolls are rather long, ovate, long-pointed,

running sixty-four to seventy to a pound; bolls open well, are fairly storm-proof, and pick well; length of lint,  $1\frac{3}{4}$  to  $1\frac{1}{4}$  inches; percentage of lint 30 to 31.5.

*Dickson's Improved* (Early Small-boll, Short-staple Group).—Developed about 1858 by David Dickson, of Oxford, Ga. This is an old variety not grown at present.

Plants are early maturing, of the strict cluster type, with one to three basal vegetative limbs; fruiting branches reduced to spurs by shortening of internodes, thus throwing the joints very close together; spurs 2 to 6 inches long, usually longer in the middle of the stalk than at the bottom or at the top; leaves very large; bolls, clustered, small, rounded shape, lint of medium length, small, fuzzy, brownish-gray; bolls per pound, 105; seed per pound, 5,670; average length of lint,  $7/8$  inch; strength of single fibers, 5.1 grams; percentage of lint, 29 to 32. Adapted from Tyler.<sup>2</sup>

*Dillon* (Medium-late, Small-boll, Short-staple Group).—Dillon is a wilt-resistant variety developed by W. A. Orton, of the U. S. Department of Agriculture, from selections from Jackson Limbless, at Dillon, S. C., in 1900. It is grown very little, if at all, at present.

Like all cluster varieties, Dillon is difficult to pick free from trash, but, owing to its resistance to wilt, its stormproof character, and its productivity, it was popular on wilt-infected soils. Plants are tall, erect, with one or two large basal vegetative branches; fruiting limbs reduced to short spurs, crowding the short-stemmed bolls into clusters; seeds small, covered with close brownish-green fuzz; bolls per pound, ninety four; seeds per pound, 5,320; length of lint,  $7/8$  inch; percentage of lint, 37. Adapted from Tyler.<sup>2</sup>

*Dirie* (Medium-late, Small-boll, Short-staple Group).—This variety was developed by W. A. Orton from a single plant selection at Troy, Ala., in 1902. The cotton from which the selection was made was grown on wilt-infected land, and this variety is considered one of the leading wilt-resistant varieties. It is still grown on the wilty lands of Georgia, Alabama, and South Carolina.

Plants are vigorous, wilt-resistant, of medium height, pyramidal, of the Peterkin type, with two or more large basal limbs; fruiting limbs long, slender, drooping; leaves of medium size; bolls of medium size, easy to pick, but very stormproof; seeds small, typically covered with a greenish-brown fuzz; bolls per pound, seventy-five; seeds per pound, 4,100; length of lint, about  $7/8$  inch; percentage of lint, 34 to 35. After Oakley.<sup>6</sup>

*Dixie-Afifi* (Intermediate Group).—This is a hybrid between Dixie and Afifi, an Egyptian variety. It resembles Dixie except in staple length. Lint length,  $1\frac{3}{4}$  inches; lint percentage, 30.

*Express* (Small-boll, Long-staple Group).—This variety was developed from a single plant selected by Dr. D. N. Shoemaker, in a mixed field of so-called "Bohemian" cotton growing near Paris, Tex., in 1904. Although early and prolific, this variety was not popular in Texas, since it did not have large bolls, was not stormproof, and was lacking in drought-resistant qualities and high lint percentage. In 1911, E. C. Ewing introduced this variety into the Mississippi Delta, in his varietal work at the Mississippi Delta Experiment Station. It did well in the Delta and soon spread over

this whole section and over much of the alluvial land in neighboring states. Since 1920, Delfos has been displacing it.

Plants are very distinct in appearance, growing somewhat rank on rich soil, tall pyramidal, open and somewhat spreading, with none to one basal vegetative branch; stem and branches long with long internodes; fruiting limbs somewhat short-jointed; leaves small to medium, light green in color; bolls rather small and long, though not so pointed as those of most long-staple cottons, seed small, covered with grayish-green fuzz; bolls per pound, seventy-three to seventy-eight; seeds per pound, 3,900; length of lint,  $1\frac{3}{16}$  inches; lint percentage, 28 to 29.

*Express-350* (Small-boll Long-staple Group).—This strain is from a selection made by Ewing in 1913 and differs from the parent plant in that plants are shorter and more compact, more prolific and more uniform.

*Express-432* (Small-boll, Long-staple Group).—This strain is from a selection made by Ewing in 1914 and developed by the writer. It differs from Express in having larger and more spreading plants, a higher lint percentage, 31 to 33, and a shorter staple,  $1\frac{5}{8}$  inches, and in being more disease-resistant.

*Lightning Express* (Small-boll, Long-staple, Group).—This strain was developed from Express-350 by the Pedigreed Seed Company, Hartsville, S. C., and differs from it in having a slightly higher lint percentage and more uniform plants.

*Floradora* (Small-boll, Long-staple Group).—This variety, which was probably Allen Long Staple to begin with, was taken from the Mississippi Delta section to Barnwell, S. C., by a cotton buyer named Coffin. For several years it was grown by Mrs. W. G. Bilmore Sims, of Barnwell, and sold under the name of Sims Long Staple. L. A. Stoney, of Allendale, Barnwell County, recognized its value and introduced it under the new name of Floradora. This cotton was grown rather widely a decade or so ago, but more recently has been displaced by earlier long-staple varieties.

Bolls per pound, eighty; seeds per pound, 3,900; length of lint,  $1\frac{3}{32}$  inches; strength of fibers, 4.5 grams; percentage of lint, 30.5. Adapted from Tyler.<sup>2</sup>

*Foster* (Big-boll, Long-staple Group).—This variety was originated by D. A. Saunders in 1904 by crossing the Sunflower and Triumph varieties. The crossing and the subsequent selection work were done on a plantation belonging to a man named Foster, after whom the cotton was named.

Plants are rather small, stocky, and compact; bolls large; foliage dense; bolls ovate, sharp-pointed; fifty to the pound; lint strong and fine in quality  $1\frac{1}{8}$  to  $1\frac{3}{8}$  inches in length; percentage of lint, 34; seed medium to small with grayish-brown tuft.

*Foster-120* (Big-boll, Long-staple Group).—This is a selection from Foster made by E. C. Ewing, in 1911, at the Mississippi Delta Experiment Station. The strain was grown rather extensively throughout the Delta of Mississippi and Arkansas for a number of years, but recently has been discarded in favor of Delfos; it is earlier and has smaller plants than the parent strain.

Plants are rather low with medium-slender stems and rather light foliage, early and prolific; bolls rather large, fifty-six to sixty-two a pound, pyriform, and long taper-pointed; percentage of lint, 30 to 32; length of staple,  $1\frac{3}{16}$

to  $1\frac{3}{4}$  inches; rather susceptible to wilt and anthracnose; well adapted to rich lands that are free from wilt.

*Griffin* (Big-boll, Long-staple Group).—This is a large-bolled variety of cotton originated by John Griffin, near Greenville, Miss., by crossing a big-boll variety with Sea Island, and practicing selection for several years. The work was begun in 1867. The strain is grown very little at present.

Plants are large and vigorous with one to three basal vegetative limbs, and medium-jointed fruiting branches; bolls large; lint long and silky but often weak; seeds of medium size, fuzzy, gray; bolls per pound, sixty-two; seeds per pound, 4,000; average length of lint,  $1\frac{3}{8}$  inches; strength of fibers, 5 grams; percentage of lint, 29.7. Adapted from Tyler.<sup>2</sup>

*Half and Half* (Round-boll, Short-staple Group).—Half and Half was originated by H. H. Summerour, of Duluth, Ga., about 1904. By individual plant selection and progeny-row testing a strain was developed which has, according to figures obtained by Mr. Summerour, ginned 56.97 per cent lint. Cook was the parent strain. Cotton buyers object to Half and Half cotton on account of its short lint, but it has a very high lint percentage, which makes it popular with many growers. It is grown extensively in hill-land regions east of the Mississippi River, and to some extent west of it.

Plants are medium early, rather compact, leaves of medium size; bolls rounded, about seventy-five to a pound; lint length,  $5\frac{1}{8}$  to  $7\frac{1}{8}$  inch; lint percentage, 40 to 44.

*Hartsville* (Big-boll, Long-staple Group).—This variety was originated by D. R. Coker, of Hartsville, S. C., from a selection made from Jones' Big Boll. It is grown to some extent in North Carolina, in South Carolina, and in the Delta regions of Arkansas and Mississippi. It is not prolific.

Fruiting limbs, rather long and long-jointed; the leaves and bolls are large; bolls per pound, sixty-two; length of lint,  $1\frac{1}{4}$  to  $1\frac{5}{16}$  inches; percentage of lint, 31.2 to 32. After Harper.<sup>7</sup>

*Hawkins Improved* (Early Small-boll, Short-staple Group).—This variety is said to have been developed by W. B. Hawkins, Nona, Ga., from a mixture of New Era, Peerless, Dickson, Herlong, and some other varieties. About 1907, it was grown over the Cotton Belt rather generally, but is now grown but little.

Plants are fairly early in maturity, tall and pyramidal in shape, with one to three basal vegetative limbs; fruiting branches numerous, short, and irregularly jointed; bolls clustered to some extent, rather small to medium in size, lint rather short; lint percentage good; leaves medium; seeds small, fuzzy, light brownish-gray; bolls per pound, seventy; seeds per pound, 4,600; average length of lint,  $2\frac{9}{32}$  inch; strength of single fibers, 5.3 grams; percentage of lint, 36.4. Adapted from Tyler.<sup>2</sup>

*Jackson or African Limbless* (Early Small-boll, Short-staple Group).—This variety was introduced in 1894 by T. W. Jackson, of Atlanta, Ga. It was similar to Dickson and Welborn's Pet, but grew taller and the leaves were somewhat larger. Like other cluster cottons, Jackson was very prolific on rich soils, where long-limbed varieties were too "weedy" in growth. It is not grown at present.

Plants are tall and slender, with one to three basal vegetative limbs; fruiting branches reduced to spurs from 1 to 6 inches long; leaves very

large; bolls crowded together on the shortened branches, four- to five-locked, rounded in shape; lint of medium length; seeds medium in size, fuzzy, brownish-gray; cotton very hard to pick free from trash; bolls per pound, ninety-eight; seeds per pound, 4,530; average length of lint,  $\frac{7}{8}$  inch; strength of single fibers, 5.2 grams; percentage of lint, 34.5. Adapted from Tyler.<sup>2</sup>

*Keew* (Small-boll, Long-staple Group).—This is a so-called "quarter" cotton that was originated many years ago by a negro, Mand Adkin, who was then living at Omega, La., by a 3 years' selection of the best plants in a 50-acre field. Atkins, Mand Atkin, Ureka, Clothorp, and Dalkreith are other names for this variety. It is grown very little, if at all at the present time.

Plants are tall and slender, pyramidal, open in growth; basal vegetative limbs, none to three, coming 6 to 8 inches from the ground; fruiting branches long and slender, and fairly short-jointed; bolls rather small and pointed; lint, soft, fine, and silky; seeds rather small, fuzzy, gray in color, a small percentage smooth and black; bolls per pound, ninety-two; seeds per pound, 4,220; average length of lint,  $1\frac{5}{32}$  inches; strength of single fibers, 5.5 grams; percentage of lint, 28.3. Adapted from Tyler.<sup>2</sup>

*King* (Early Small-boll, Short-staple Group).—In 1890, T. J. King, formerly of Louisburg, N. C., later of Richmond, Va., discovered a very prolific stalk of cotton in his field of Sugar Loaf, and from this stalk he developed what he called King, or King's Improved. Some years afterward he sent seed of the Sugar Loaf and of his new improvement to several experiment stations, and the reports convinced him that his new strain was practically identical with the parent variety. The variety is sold under the names King's Improved, King's Early, Mascot, Greer, Spotted Bloom, Ninety Day, and Little Texas. Simpkins and Simpkins Ideal are very similar if not identical. Adapted from Tyler<sup>2</sup> and others.

*Lewis Prize* (Intermediate Group).—This variety was developed by W. B. F. Lewis, Lewiston, La. It is not grown extensively now.

Plants are lacking in uniformity, some closely semiclustered, other more open and long-branched; bolls of medium size, rounded; seeds fuzzy brown; lint of medium length, and high in lint percentage; bolls per pound, eighty-one; seeds per pound, 4,880; average length of lint,  $1\frac{5}{16}$  inch; strength of single fibers, 6.7 grams; percentage of lint, 38.3. Adapted from Tyler.<sup>2</sup>

*Lone Star* (Big-boll, Medium-staple Group).—This variety was developed by Dr. D. A. Saunders from a single superior plant found in a field of Jackson cotton in the Colorado river bottom, near Smithville, Tex., in 1905. It is grown extensively at present in Arkansas, Oklahoma, and Texas.

Plants are of medium height with one to four basal vegetative limbs; main stem short-jointed; fruiting branches numerous, long, medium short-jointed; leaves medium to large, very dark green; bolls very large, round, or broadly ovate, with very short, blunt points; bolls per pound, thirty-five to forty-five; fiber, very strong; length of lint, 1 to  $1\frac{1}{8}$  inches; lint percentage, 38 to 40.

The foregoing description is from *Cotton Seed Distribution Circular* issued by the Bureau of Plant Industry, U. S. Department of Agriculture, in 1919. Descriptions by others give the variety a boll size of from forty-eight to fifty-eight bolls per pound, and a lint percentage of from 35 to 38.

*Meade* (Big-boll, Long-staple Group).—This variety originated from a single plant selection made in 1912 by Rowland M. Meade, of the U. S. Department of Agriculture, from a field of Blackseed, or Black Rattler, at Clarksville, Tex. It has been introduced into the Sea Island district of Georgia and South Carolina to replace Sea Island cotton, which cannot be grown profitably in regions infested with boll weevils.

Plants are erect, of average height, with regular internodes of medium length on both the main stalk and the vegetative branches; internodes of the fruiting branches, rather long, with little tendency to take the shortened cluster form; leaves of medium size and rather thin texture; bolls of medium size, with a thin bur, opening readily under humid conditions; seeds large, about 3,000 to the pound, nearly naked after the lint has been removed, brownish black, slightly tufted at the end; lint,  $1\frac{1}{2}$  to  $1\frac{1}{16}$  inches, uniform, with good luster, scarcely distinguishable from Sea Island lint when properly ginned; lint percentage, 26.

*Mexican Big Boll* (Big-boll, Medium-staple Group).—According to Tracy,<sup>1</sup> Mexican cotton was brought from Mexico City by Walter Burling in 1806, and introduced into South Carolina. This was an early ancestor of several of our recent short-staple varieties.

*Mexican-6* (Big-boll, Medium-staple Group).—This is a selection from a cotton known in South Carolina as Mexican Big Boll, and is probably derived from the old Mexican variety. In 1914, Dr. R. Y. Winters, of the North Carolina Station, obtained seed from J. D. Hope, of Sharron, S. C., and subsequently made selections.

Mexican-6 has medium-sized plants, which are early and prolific for a big-boll variety; leaves of moderate size; bolls ovate, fifty-five to sixty to the pound; length of staple, 1 to  $1\frac{1}{16}$  inches; lint percentage, 34 to 35.

*Mortage Lifter* (Big-boll, Medium-staple Group).—This is a trade name for the variety Wyche (see description under that variety). Adapted from Tyler.<sup>2</sup>

*Nankeen*.—This is an old cotton almost extinct except in a few places where home weaving is carried on. It is hardly worthy of being called a variety since it was probably obtained by preserving the seeds of the yellow reversions or possible mutations, which sometimes occur in cotton of several different varieties. Except in color of lint, Nankeen resembles the common cotton grown in the same region. Adapted from Tyler.<sup>2</sup>

*Okra or Okra Leaf* (Early Small-boll, Short-staple Group).—This was a very distinct cotton grown as long ago as 1837; it has been preserved more as a curiosity than as a field crop. Okra-leaved plants are occasionally found among the plants of different varieties. These are probably reversions from ancestral hybrids.

Okra Leaf cotton has been generally described as an early cotton, with small bolls, short lint, and small and fuzzy seeds. The cotton wastes badly during storms. Plants are very similar to King in most respects; the leaves are very large, resembling those of the okra plant; bolls usually four-locked, opening widely; bolls per pound, 108; seeds per pound, 5,670; average length of lint,  $2\frac{5}{32}$  inch; strength of fibers, 5.2 grams; percentage of lint, 33. Adapted from Tyler.<sup>2</sup>

*Parker* (Early Small-boll, Short-staple Group).—This was a Mississippi variety grown by John M. Parker, at Maxime, Miss., and distributed to some extent. It later became mixed with Black Rattler and other varieties. It is probably now extinct.

Plants are rather tall and slender, with one to three long basal limbs, and slender, fairly short-jointed fruiting limbs; leaves of medium size; bolls small, three-, four-, and five-locked; seeds, medium in size, fuzzy, gray, or greenish-gray; bolls per pound, ninety-six; seeds per pound, 3,800; average length of lint, 1 inch; strength of single fibers, 5.2 grams; percentage of lint, 30. Adapted from Tyler.<sup>2</sup>

*Peeler* (Small-boll, Long-staple Group).—This is an old variety said to have originated in Warren County, Mississippi, in 1864, and formerly grown extensively but now nearly extinct.

Plants are of medium height, two to three basal limbs, sometimes none, coming out 5 to 6 inches above the ground, making the plants somewhat long-shanked; fruiting branches slender, joints of medium length; bolls, small, three-, four-, and five-locked; seeds medium in size, covered by sparse fuzz; lint long, fine, and silky; bolls per pound, 121; seeds per pound, 3,850; average length of lint, 1 $\frac{3}{8}$  inches; strength of single fibers, 4.1 grams; percentage of lint, 26.5. Adapted from Tyler.<sup>2</sup>

*Peerless* (Medium-late, Small-boll, Short-staple Group).—The origin of this variety is unknown. It was a popular and standard variety for several years, but was allowed to deteriorate, and is not grown now.

Plants are 3 to 4 feet high, pyramidal in shape; one to three basal limbs; fruiting branches short and irregularly jointed; bolls small to medium in size; seeds rather small, fuzzy, greenish- or brownish-gray; bolls per pound, sixty-nine; seed per pound, 4,550; average length of lint, 7/8 inch; strength of single fibers, 5 grams; percentage of lint, 31. Adapted from Tyler.<sup>2</sup>

*Peterkin* (Medium-late, Small-boll, Short-staple Group).—This variety was developed by J. A. Peterkin, Fort Motte, Orangeburg County, South Carolina, about 1870. The original strain is grown but little at present, but Dixie and some other similar varieties are cultivated.

Plants are slender in growth, one to three basal limbs, fruiting branches long, slender, with almost no tendency toward the semicluster habit; plants somewhat late in maturity; bolls medium to small, 70 per cent five-locked, opening widely, but cotton retained fairly well during storms; seeds small, covered with a short, brownish-gray fuzz, a small percentage smooth and black; bolls per pound, eighty-two and a half; seeds per pound, 5,300; average length of lint, 7/8 inch; average strength of fibers, 5.8 grams; percentage of lint, 39.6.

Texas Oak and Texas Wood are synonyms of Peterkin. Adapted from Tyler.<sup>2</sup>

*Petit Gulf* (Intermediate Group).—This variety was developed in 1840 by Col. H. W. Vick, of Vicksburg, Miss. By 1846, it had become very popular, and large quantities of seed were shipped from Petit Gulf, a small shipping point on the Mississippi River below Vicksburg.

The plant is late in maturing. It is large and straggling, with three or more vegetative limbs; fruiting branches slender and long-jointed; leaves medium in size, bolls rather small; seeds of medium size, mostly fuzzy,

brownish-gray; bolls per pound, seventy to eighty; seeds per pound, 4,200; length of lint,  $\frac{7}{8}$  to  $1\frac{1}{8}$  inches; percentage of lint, 30 to 32. Adapted from Tyler.<sup>2</sup>

*Pulnott* (Intermediate Group).—This variety was originated by William Pulnott, formerly of High Shoals, Oconee County, Georgia. At one time it was grown extensively in Georgia, but has been recently largely superseded by Cook.

Plants are stocky and compact in growth, with one to three basal limbs; fruiting branches rather short and irregularly jointed, leaves of medium size; bolls large, 66 per cent five-locked; seeds medium in size, fuzzy, brownish- or greenish-gray; bolls per pound, fifty-eight; seeds per pound, 3,810; average length of lint,  $1\frac{5}{16}$  inch; strength of single fibers, 5.9 grams; percentage of lint, 35.1. Adapted from Tyler.<sup>2</sup>

*Rowden* (Big-boll Medium-staple Group).—This variety was developed from Bohemian cotton by Rowden Brothers, at Wills Point, Van Zandt County, Texas, about 1890. It is medium early in maturity. It is still a popular variety in Texas, Oklahoma, and parts of Arkansas.

Plants are vigorous and stocky in growth; one to three basal limbs; fruiting branches vary in length from 2 feet at the base to 6 inches on upper part of plant; joints regular and of medium length; bolls large and hang downward when ripe, giving the cotton some protection from the weather; seeds large, fuzzy, grayish-white; bolls per pound fifty to sixty; seeds per pound, 3,360; average length of lint,  $1\frac{5}{16}$  inch; strength of single fibers, 6.3 grams; percentage of lint, 35.4. Adapted from Tyler.<sup>2</sup>

*Miller* (Big-boll, Medium-staple Group).—This is a strain of Rowden grown and distributed by A. D. Miller, Blue Springs, Miss. It is grown to some extent in the hill sections of Mississippi and Tennessee.

*Rublee* (Early Small-boll, Short-staple Group).—This cotton was developed by C. A. Rublee, Seagoville, Tex. It is not grown extensively at present.

Plants are semicluster in habit of growth, imperfectly defoliate, many plants retaining their leaves and putting on squares late in the fall; bolls medium to small in size; seeds medium in size, fuzzy, light greenish- or brownish-gray; bolls per pound, seventy; seeds per pound, 3,600; average length of lint,  $\frac{7}{8}$  inch; strength of single fibers, 6.3 grams; percentage of lint, 33. Adapted from Tyler.<sup>2</sup>

*Russell* (Big-boll, Medium-staple Group).—Known also as Big Boll Green Seed and Ozier Big Boll. Originated in 1895 by J. T. Russell from a single stalk found in a field of mixed Truitt at Alexander City, Ala. This variety was widely grown throughout the Cotton Belt in 1907, but more recently has been largely supplanted by other varieties.

Plants are large growing, vigorous, with one to three basal limbs; fruiting branches long; joints of medium length; leaves large; bolls large, four- to five-locked; fairly stormproof; the burs very thick; seeds large, covered by a dark-green fuzz; bolls per pound, fifty-six; seeds per pound, 3,100; length of lint,  $3\frac{1}{32}$  inch; strength of single fibers, 5.5 grams; percentage of lint, 30.9. Adapted from Tyler.<sup>2</sup>

*Salsbury* (Small-boll, Long-staple Group).—This variety was developed by E. C. Ewing, at Scott, Miss., in 1916, from a cross of Wannamaker Cleveland and Express-350. It is grown at present in Mississippi and Arkansas.

Plants are erect, of vigorous growth; foliage intermediate between its parents, Wannamaker Cleveland and Express-350; somewhat resistant to wilt; of rather rank growth on rich land; fruiting limbs long and long-jointed; bolls per pound, seventy-five to eighty; lint percentage, 31 to 31.5; length of lint,  $1\frac{1}{16}$  full to  $1\frac{1}{8}$  inches; strength of fiber good.

*Southern Hope* (Small-boll, Long-staple Group).—This is an old variety developed by Col. F. Robiew, of Louisiana, but it is not grown now.

Plants are tall, slender in growth, with one to three basal limbs; fruiting limbs quite long and slender; leaves medium to small; bolls medium in size, opening well; seeds fuzzy, light greenish-gray; bolls per pound, seventy-three; seeds per pound, 4,160; average length of lint,  $1\frac{7}{32}$  inches; percentage of lint, 31.2. Adapted from Tyler.<sup>2</sup>

*Spruill's Green Seed* (Early Small-boll, Short-staple Group).—This variety was developed by A. M. Spruill, Brompton, Ala., and is not grown extensively now.

Plants are not uniform, some as early as King, others later in maturity; bolls medium in size, seeds small; bolls per pound, seventy-two; seeds per pound, 4,220; average length of lint,  $1\frac{5}{16}$  inch; percentage of lint, 32.8. Adapted from Tyler.<sup>2</sup>

*Sugar Loaf* (Early Small-boll, Short-staple Group).—This is an old variety which has been grown in North Carolina for many years. Selections from Sugar Loaf, known commercially as Kings, or King's Improved, and Simpkins are grown rather extensively at present in the southern and eastern sections of the Cotton Belt. The variety and its derivatives are characterized by blooms with red or purple spots at the base of the petals.

Plants are slender, one to three basal limbs fruiting branches slender and short-jointed, but with little or no tendency to semicluster; leaves medium to small in size; bolls small, three-, four-, and five-locked, the majority four-locked; seeds small, covered with a short fuzz, brownish-gray in color; bolls per pound, ninety-three; seeds per pound, 5,600; average length of lint,  $2\frac{9}{32}$  inch; percentage of lint, 35. Adapted from Tyler.<sup>2</sup>

*Sunflower* (Small-boll, Long-staple Group).—Sunflower was developed by Marx Schaefer of Yazoo City, Miss., by means of mass selection. The original seed were bought at an oil mill. It is barely distinguishable from pure Floradora and some of the forms of Allen. Sunflower was a standard variety for a number of years, but since boll weevils have become widely distributed its use has been largely discontinued.

Plants are tall and pyramidal, with slight tendency toward the semicluster type; one to three basal limbs; fruiting branches slender and irregularly jointed; leaves medium in size; bolls small, five-locked; lint very fine, long, and silky; seeds medium in size, fuzzy, gray, or light greenish-gray; bolls per pound, ninety; seeds per pound, 4,320; length of lint,  $1\frac{3}{8}$  inches; strength of single fibers, 4.9 grams; percentage of lint, 25. Adapted from Tyler.<sup>2</sup>

*Texas Bur* (Big-boll, Medium-staple Group).—C. E. Smith, Locust Grove, Ga., introduced this cotton, which was probably a strain of the old Texas Stormproof. It is grown to a very limited extent at present.

Plants are stocky in growth, usually two basal limbs, rather heavy; fruiting branches with joints of medium length, leaves large; bolls large, four- and five-locked, seeds rather large, fuzzy, gray or brownish-gray; bolls per

pound, sixty-seven; seeds per pound, 3,680; average length of lint,  $2\frac{3}{32}$  inch; strength of single fibers, 7 grams; percentage of lint, 37.1. Adapted from Tyler.<sup>2</sup>

*Toole* (Medium-late, Small-boll, Short-staple Group).—This is a standard strain of Peterkin developed by W. W. Toole, Augusta, Ga. It is wilt-resistant and is grown in Georgia and other districts where cotton wilt is troublesome. Plants are similar to Peterkin, but with a slight tendency to semicluster.

Bolls are larger than those of Peterkin, 50 per cent 5-locked; seeds small, fuzzy, light brownish-gray; bolls per pound, seventy-three; seeds per pound, 5,110; average length of lint,  $1\frac{5}{16}$  inch; strength of single fibers, 6.7 grams; percentage of lint 37.5. Adapted from Tyler.<sup>2</sup>

*Covington-Toole* (Medium-late, Small-boll, Short-staple Group).—This strain is a selection from Toole, made by W. F. Covington, Headland, Ala. It shows a decided resistance to wilt and is planted rather extensively on wilty soils in the eastern states.

*Trice* (Early, Small-boll, Short-staple Group).—This variety was developed by Prof. S. M. Bain from a single stalk found on the farm of Luke Trice, near Henderson, Chester County, Tennessee, in 1907. This variety is considered one of the earliest-maturing varieties grown today. It is grown extensively in northern parts of the Cotton Belt, especially in Tennessee, Kentucky, and Missouri.

Plants are 2 to 5 feet high, frequently with few basal limbs, very prolific; fruiting branches numerous, medium in length, and short-jointed; leaves of medium size, light-green bolls medium to large, ovate, often angular, three-to five-locked; seeds medium to small, covered with whitish or brownish tuft; bolls per pound, seventy to eighty; seeds per pound, 3,600; character of fiber fair; length of staple,  $1\frac{5}{16}$  to  $1\frac{1}{16}$  inches; percentage of lint, 31 to 33. Adapted from Oakley.<sup>6</sup>

*Mississippi Station Trice*.—This strain differs from the parent plant in having slightly more compact plants, smaller bolls, seventy-five to eighty-five per pound, and longer staple, 1 to  $1\frac{3}{32}$  inches. This strain is very early, a good yielder, and adapted to rich lands that are free of wilt. It was selected by the Mississippi Experiment Station.

*Triumph* (Big-boll, Medium-staple Group).—Developed by A. D. Mebane, of Lockhart, Tex., from Boykin Stormproof, in 1889. It is grown, extensively west of the Mississippi River, especially in Texas, Oklahoma and Arizona.

Plants are quite similar to Boykin, but earlier in maturity. The bolls and seeds are somewhat smaller and the percentage of lint is much higher. Bolls per pound, fifty-six; seeds per pound, 3,600; average length of lint, 1 to  $1\frac{1}{16}$  inches; strength of single fibers, 6.7 grams; percentage of lint 36 to 38. Adapted from Tyler.<sup>2</sup>

*Truitt* (Big-boll Medium-staple Group).—A standard variety developed by George W. Truitt, of Lagrange, Troup County, Georgia, from selections from Wyche. It is grown in Texas at present.

Plants are not uniform, semiclustered in growth; one to three basal limbs, heavy; fruiting branches, medium to short-jointed; leaves large; bolls large; seeds large, fuzzy, gray; bolls per pound, fifty-six; seeds per pound, 3,660;

lint length,  $2\frac{9}{32}$  inch; strength of single fibers, 6.6 grams; percentage of lint, 34. Adapted from Tyler.<sup>2</sup>

*Webber* (Big-boll, Long-staple Group).—Originated by D. R. Coker, of Hartsville, S. C., from a selection from Columbia. It is grown most extensively in South Carolina and in the alluvial regions in Arkansas and Mississippi.

Plants are vigorous, growing somewhat rank in rich soils; fruiting limbs of medium length long-jointed, and drooping; leaves very large and rather dark green color; bolls medium large; bolls per pound, 60; strength of fiber, good; length of lint,  $1\frac{3}{16}$  to  $1\frac{1}{4}$  inches; percentage of lint, 30 to 31.5. After Harper.<sup>7</sup>

*Webber-49* (Big-boll Long-staple Group).—This is a strain of Webber developed by the Pedigreed Seed Company at Hartsville, S. C. It differs from the parent strain in being lower and more stocky in growth, in being earlier and more prolific, and in having somewhat smaller bolls, sixty-four to sixty-eight per pound; character of fiber good; length of staple,  $1\frac{3}{4}$  to  $1\frac{5}{16}$  inches.

*Delta-type Webber* (Big-boll, Long-staple Group).—This is a recent strain of Webber developed by the Pedigreed Seed Company, Hartsville, S. C., from a selection of Webber-82. It is a little more upright in growth than Webber-49 and has rather short fruit branches. The bolls are large, and the character of the staple is excellent; length of staple,  $1\frac{3}{4}$  to  $1\frac{3}{8}$  inches; lint percentage, 30 to 31.

*Welborn's Pet* (Early Small-boll, Short-staple Group).—Originated by Jeff Welborn, of New Boston, Tex., in 1881. It is not grown at present.

Plants are tall, one to three basal limbs; fruiting branches reduced to short spurs; leaves large; bolls rounded, four- to five-locked; seeds medium in size, fuzzy, or brownish-gray, a few nearly smooth, dark brown; bolls per pound, seventy; seeds per pounds, 3,860; length of lint,  $\frac{7}{8}$  inch; percentage of lint, 33.4. Adapted from Tyler.<sup>2</sup>

*Wyche or Jones Improved* (Big-boll Medium-staple Group).—This is one of the oldest big-boll cottons grown in America. It is said to have been introduced from Algiers by the Wyche brothers about 1857. After the death of Mr. Wyche, the variety was propagated and seed were distributed by J. F. Jones, hence it is sometimes called Jones Improved. Truitt, Russell, Columbia, and Webber trace their ancestry to Wyche.

Plants are vigorous and prolific; wide-spreading branches near the base, upper branches usually short; bolls large, ovate, blunt-pointed, five-locked, open well; seeds medium large, weighing 0.13 to 0.14 gram, covered with a grayish fuzz and well covered with lint; lint strong, 1 to  $1\frac{1}{8}$  inches; percentage of lint, 31 to 32; season, medium late. Adapted from Webber.<sup>8</sup>

**Egyptian Varieties in America.**—Several Egyptian varieties have been grown experimentally in America but none have proved satisfactory except the selections from Afifi listed below.

*Yuma*.—This is a variety of Egyptian cotton developed by the U. S. Department of Agriculture, in Arizona, in 1908. It arose as a sport or

mutant from Afifi. It was grown in Arizona rather extensively for a time, but has been displaced more recently by Pima. It differs from Afifi variety in having a longer length of lint, averaging about  $1\frac{1}{2}$  inches; it has a pale pinkish-buff color as opposed to the brown color of the Afifi cotton; also the bolls are larger than the bolls of the Afifi variety. Adapted from U. S. Department of Agriculture *Bulletin* 38, 1913.

*Pima*.—This variety originated from a single stalk selection discovered in a field of Yuma cotton, Sacaton, Ariz. The staple is longer and the quality of fiber is better than that of Yuma; staple length  $1\frac{9}{16}$  to  $1\frac{13}{16}$  inches; it is slightly more prolific than Yuma and early. Adapted from U. S. Department of Agriculture *Circular* 247.

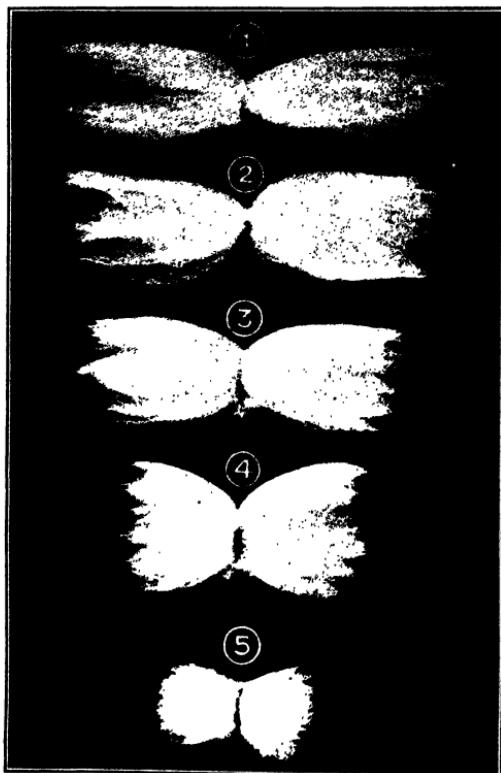


FIG. 14.—Length of staple of five important types of cotton. Lint combed. (1) Sea Island. (2) Egyptian. (3) Upland long staple. (4) Upland short staple. (5) Asiatic type. (After Meloy.)

**Sea Island Varieties.**—Varieties of Sea Island cotton are not so permanent nor so well known as Upland varieties. To keep the strains up to a high standard it was necessary to do much breeding work. In many instances the plantation selected and

continued to breed each year its own particular strain. In case seed were sold, which was not common, the variety designation given them was only the name of the breeder or grower. Inland growers usually bought seed each year, and frequently from different parties. The plantation breeder grew from a new selection each year, and frequently changed the type to some extent. Hinson, Seabrook, Rivers, and La Roche are names of prominent breeders mentioned by Orton.<sup>4</sup> These names have been used in the sense of variety names.



FIG. 15.—Various cotton varieties in breeding plat. *a.* Upland Okra-leaf. *b.* Upland, Nankeen. *c.* Upland hybrid, Triumph  $\times$  Express. *d.* Sea Island. *e.* Pima Egyptian.

**Foreign Varieties.**—Each cotton-producing country has its own varieties; some countries have many. The following lists contain the more important varieties, with some brief data.

**Varieties Grown in India.**—The Report of the Indian Cotton Committee for 1919 lists some forty varieties and gives brief data on each. Those listed in Table II are the ones grown most extensively:

TABLE II.—INDIAN VARIETIES

Variety	Length staple, inches	Lint, per cent	Esti- mated area, acres	Estima- ted yield, bales	Where grown
Bani.....	1 - 1½	25	840,000	168,000	830,000 acres in Hyder- abad
Buri.....	2½ - 1	31	2,000	500	
Mixed varieties.....	5½ - 6½	33	1,400,000	300,000	Central India states
Malwa.....	6½ - 7½	25	112,000	22,000	Malwa Plateau
Mixed varieties.....	5½ - 6½	25-40	3,700,000	571,000	Berar and Central Pro- vinces
Rozeum.....	5½ - 5½	40	700,000	180,000	Berar and adjoining tracts
Dholleras (group of varie- ties).....	4½ - 7½	32-40	2,100,000	585,000	North Gujarat, Broach dis- trict, Ahmadabad, other regions
Sind.....	3½ - 5½	35	245,000	67,000	Sind
Broach varieties.....	3½ - 1	31-35	1,210,000	280,000	Surat and Broach districts
Kunupta Dharwar.....	7½	26	1,200,000	240,000	Satara district southward
Coconadas.....	5½ - 7½	23	261,000	40,000	Madras and Hyderabad
Karunganni.....	7½	32	220,000	50,000	Tinnevelly, Madura and Rannad
Tinnevelly.....	9½ - 7½	27	320,000	84,000	Madura, Rannad
Cambodia.....	5½ - 1½	33	471,000	200,000	Madras, Bombay, Central Provinces and Hyderabad
Punjab American.....	7½	32-33	276,000	100,000	Punjab Canal Colonies
Cawnpore American.....	7½ - 1	31	2,000	500	Cawnpore
Wa-gale.....	5½ - 9½	30	214,000	47,250	Burma

**Varieties Grown in China.**—There are many native varieties of cotton grown in China and several imported ones. Professor S. C. Wang, professor of Cotton Industries in the University of Nantung, estimates that about 200 varieties have been listed. He thinks that the majority of these are synonyms and that there are but a comparatively small number of true or distinct varieties. The varieties grown, according to Wang, may be divided into three groups: (1) The American group, which includes Trice, Lone Star, Cleveland Big Boll, Bank Account, King, Acala, and Columbia. Sea Island and Egyptians are grown experimentally but are of little economic value. (2) The Indian group, which includes the so-called Chicken Foot cotton of China. *G. arboreum*, Linn. var. *neglecta* Watt., is predominant, but var. *rosea* and var. *assamica* are also probably represented. These cottons were introduced long ago and have become thoroughly acclimated. The staple, in quality and length, is similar to that of American

short-staple Uplands, the length being about  $\frac{7}{8}$  inch. (3) The native group includes numerous varieties belonging to the species *G. nanking*, Meyen. Most of these take the name of the locality in which they are grown. Nantungchow and Gar Gar are two varieties mentioned by Wang. The native varieties have a very coarse, short staple, averaging about  $\frac{5}{8}$  inch in length.

**Egyptian Varieties.**\*—The leading variety in Egypt at present is Sakel, or Sakellaridis. In 1921, it made 77 per cent of the entire crop and was grown almost exclusively in the Delta, or from Cairo northward. This variety has increased in popularity rapidly. In 1911, the year that it was first recorded statistically as a separate variety, it produced 7 per cent of the total crop. The cotton is creamy white, with a staple about 38 millimeters long ( $1\frac{1}{3}$  inches). It has displaced the older brown varieties, Afifi, Abbassi, and Yanovitch. Cazouli, a new variety similar to Sakellaridis, is being grown increasingly. Other old varieties that have largely disappeared are Nubari, Assili, Fathi, and Voltos. These varieties were all grown in Lower Egypt, or in the Delta district. Ashmouni, which in 1921 produced 13.2 per cent of the Egyptian crop, and Zagora, which produced 7.2 per cent, are the other leading varieties. They are grown in Upper Egypt. Zagora is displacing the former variety. Sea Island and American Upland varieties have been tried in Egypt, but are not liked. The former yields poorly, and the latter has fiber too coarse and short.

**South African Varieties.**†—Cotton growing began in South Africa about 1850, but owing to lack of labor, distance from market, and the counter attraction of diamond mining, the industry has not flourished. In 1920 only 2,000 bales were produced. American varieties are grown largely, the following being the principal ones: Baneroff, Improved Baneroff, King, Cleveland, Cook's Long Staple, Russell, Toole, Allen, and Sunflower. Other varieties grown are Nyasaland Upland, Union, and Loffler.

\* Dr. George F. Freeman, formerly botanist for the Société Sultanienne D'Agriculture, Cairo, Egypt, kindly furnished information about cotton varieties grown in Egypt.

† Information about South African varieties was kindly given by W. J. Lugard, Jr., of Holland, who has done experimental work with cotton in that region.

**Varieties in Argentina.\***—There are no native varieties, but several American short-staple Uplands have been imported, acclimatized, and are grown in a limited way. A variety known as "Chaco," introduced from Louisiana about 1870, is the leading variety. Others grown are Texas Wood, Dixon, and Simpkins.

**Peruvian Varieties.†**—The principal varieties of cotton produced in Peru are: Full rough (Aspero), which has a staple about  $1\frac{1}{4}$  inches and a particularly crinkly rough fiber especially adapted to mixing with wool; semirough (Semi-Aspero), the same variety as the Aspero produced under different climatic conditions, has less of the roughness or crinkly characteristics of the Aspero, and a staple of  $1\frac{3}{16}$  inches; Egipto, or Suave, an acclimatized variety of the American Uplands with a staple length of  $1\frac{1}{16}$  to  $1\frac{1}{8}$  inches; Tanguis, a new variety recently developed, has a very white fiber averaging  $1\frac{5}{16}$  up to  $1\frac{1}{2}$  inches; Afifi, which was originally grown from Egyptian seed, averaging  $1\frac{1}{4}$  inches in length of staple. There are a few other varieties, among which is Sea Island. About one-third of the cotton produced is from the variety Suave. Afifi and Tanguis rank next in order of production, with 28 and 22 per cent, respectively.

**Brazilian Varieties.**—Brazil has many varieties, both native and foreign. Both long- and short-staple varieties have been grown together promiscuously and allowed to mix. Consequently, many of the varieties are badly hybridized and are lacking in uniformity. The following data on the leading cotton varieties in Brazil were kindly furnished by O. F. Lamartine, of Natal, Rio Grande do Norte, Brazil.

\* Notes on cotton varieties in Argentina were sent by Hon. Carlos D. Girola, of Buenos Aires.

† From information furnished by Acting Commercial Dunn of Lima, Peru.

## PRINCIPAL VARIETIES OF COTTON GROWN IN BRAZIL

Variety	Type	Length staple, milli- meters	Lint, per cent	Notes
Mocó <sup>a</sup> or Seridó.....	<i>G. peruvianum</i> , tree type	35-45	30-32	Variety limited to the Seridó section of northeast Brazil and adjacent valleys. Belongs to tree-cotton group; perennial, 5 to 8 feet high; bolls small; flowers lemon-yellow color. Plants very resistant to drought. Known to yield 450 to 480 pounds lint cotton per acre.
Rigueza or Verde.....	<i>G. peruvianum</i> , tree type	32-35	26-28	Native variety with fuzzy green seeds; lint very silky and strong. Requires a richer soil than Mocó. Grown in the northeastern states and along the S. Francisco River Valley.
Quebradinho.....	<i>G. vitifolium</i> , tree type	25-35	28	Very similar to Mocó. Known by different names in different states. Mostly grown in the central states (Minas), and in the extreme northern section (Maranhão, etc.).
Rim or Kidney cotton	<i>G. brasiliense</i> , tree type	30	18-20	Lint very strong and sought by the natives for home spinning. Used to a limited extent only. Seeds small, adhering in a kidney-shaped mass. Grown in S. Francisco Valley in the states of Minas and Bahia.
Russell Big Boll Sunbeam Up Right Paulo Souza Carioba Nova Paulista and others	Herbaceous type, im- ported Ameri- can Uplands	23-30	33-34	Grown in Central Brazil in the states of São Paulo and Minas principally; also in the northeastern section along the seacoast; are reported to mature there in 90 days or less. In São Paulo on rich soils yields as high as 800 pounds lint cotton per acre have been reported. The varieties Nova Paulista, Paulo Souza, and Carioba are hybrids, coming from crosses made in São Paulo. Carioba is a cross between Webber and Russell Big Boll.

<sup>a</sup> In the Seridó district there is grown also a variety or strain called Mocó-sinho (Little Mocó), which resembles the true Mocó but has very small black seed and a fiber considered stronger.

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## CHAPTER IV

### COTTON PLANTS: THEIR FORM, STRUCTURE, AND GENERAL CHARACTERISTICS

The study of plant form is basic. It is only through, or by means of, a study of form that differences and resemblances may be recognized and classification made. The physiologist observes form and structure as an expression of physiological laws and effects. The plant breeder, in endeavoring to produce new and more desirable varieties, studies closely differences in form appearing among the plants with which he is working and bases his selections on striking points of dissimilarity observed.

The cotton plants growing in a single field show considerable variation, but a much greater range of form is met when a survey is made of plants in the various countries in which cotton is found growing. Within the tropics, the natural home of cotton, the plant is commonly a perennial, and some species attain a height of 15 to 20 feet, being known as tree cottons. In the American Cotton Belt, the plant has been forced to assume the annual habit on account of the frosts and freezes of winter. Here it is a soft stemmed shrub, much branched, and varying in height from 2 to 6 feet.

**Framework of a Mature Cotton Plant.**—A mature plant has a prominent, erect main stem, which has a growing point, or plumule, at the apex. The growth of the main stem is therefore monopodial, but the growth of secondary branches and branches of higher orders is either monopodial or sympodial. The length of the stem is determined mainly by soil and water conditions, but there is, of course, a difference due to species or variety. Certain varieties, such as Trice, King, and Delfos, are somewhat determinate in their stem growth—there is a tendency for the stem to stop growing in length comparatively early in the season.

The general shape or outline of plants ranges from columnar to rounded. The shape is determined by length of branches. Short branches throughout the whole length of stem produce the columnar form; long branches at the base with successively

shorter branches toward the top produce the conical or sugar-loaf form; and long branches high on the stem, the rounded or apple-tree form.

Large leaves arise from the stem in alternate order and are arranged about the stem in regular spirals. The common arrangement, or phyllotaxy as it is called, for American cottons is three-eighths of a turn about the stem between successive leaves: or, expressed in another way, from one leaf to the next directly above it there are eight leaves and the spiral passes around the



FIG. 16.—A well-fruited cotton plant with unopened bolls. (a) main stem; (b) basal vegetative branches; (c) fruit branches.

stem three times. This is designated as  $\frac{3}{8}$  phyllotaxy. The course of the spiral is either to the right or to the left. Other types of phyllotaxy found among cottons are  $\frac{1}{3}$ ,  $\frac{2}{5}$ , and  $\frac{5}{13}$ . Old World cottons commonly have the  $\frac{1}{3}$  arrangement. The leaves on the branches have the same order of phyllotaxy as those on the main stem, but the spiral may run in the opposite direction on a part of the branches.

Each leaf has two buds, or at least the rudiments of buds, in its axil—the angle between the leaf stalk and the stem to which it is attached. One of these buds occupies a central position and

is a true axillary bud. The other bud has a position to one side of the axillary bud and is known as a lateral or extraaxillary bud. It may be found on either side of the central bud. The axillary buds produce only vegetative branches, that is, branches that bear flowers and fruit only after again branching (Fig. 16b).

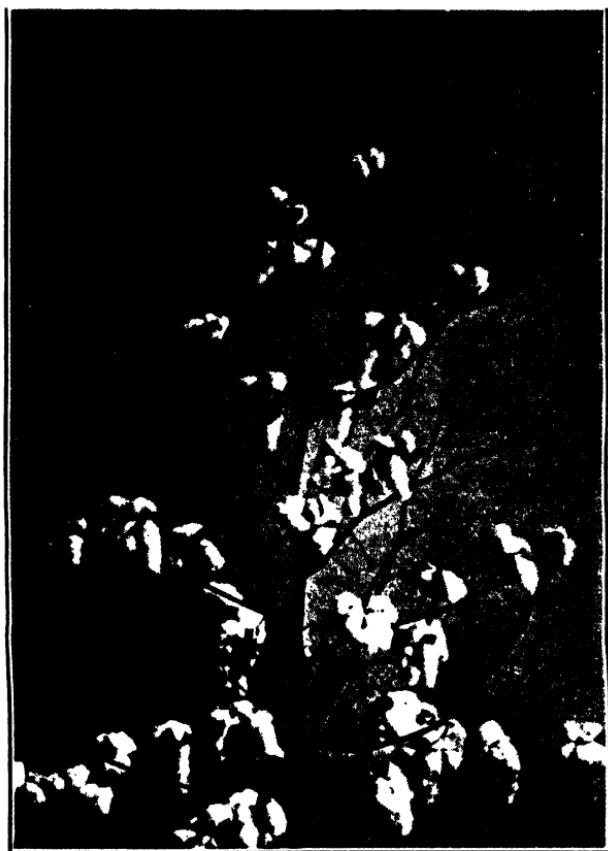


FIG. 17.—A cotton plant showing framework, open bolls, and both vegetative and fruiting branches arising from the same node on the main stem. (After

Most of the lateral buds produce fruit branches, which bear flowers and fruit directly (Fig. 16c). Under certain conditions the lateral buds may make vegetative branches. Usually not more than one to four of the axillary buds on the lower part of the plant grow into branches. The others remain dormant. Both of the buds in the leaf axil may make branches (Fig. 17).

Rainy weather and rich land may cause a higher percentage of vegetative branches to develop, and thus produce extra vegetative growth at the expense of the fruit branches. Cook and Meade<sup>2</sup> report that vegetative branches are much more numerous on plants grown from newly imported seed than on acclimatized strains. While an excessive development of vegetative branches is not desirable, two or three are not objectionable. Some of the most prolific varieties have from two to four vegetative branches to the plant.

The height and the spread of plants are determined largely by the length of internodes in stem and branches. It is generally thought that plants with short internodes are earlier than ones with long internodes, but the variety Express appears to be an exception to this rule. It is one of the earliest Upland varieties; yet it is rather long-jointed.

**Arrangement of Leaves and Flowers on Fruiting Branches.**—The leaves of fruiting branches lack the spiral arrangement that is found on the main stem and vegetative branches. The leaves appear to be somewhat two-ranked. The flower buds do not come from the leaf axils but appear to arise independently. It has been suggested by Cook and Meade<sup>2</sup> that fruit branches appear to be sympodial in their growth, that each flower terminates a joint, and that further growth is from a lateral bud. Leake,<sup>3</sup> in discussing the morphology of types of Indian cottons, says that the flowers are not concentrated in any well-defined inflorescence, but are developed on the sympodial branches from terminal buds.

**Structure of Stem.**—Cotton stems have a moderately thick, tough bark in which bast fibers are prominent (Fig. 18). The bark has been used to a limited extent as a coarse fiber material, and it has been proposed as a possible source of fiber for cotton bagging for bales. The outer layer of the bark is more or less corky. It is of a yellowish-brown color on the older parts of stems and greenish to reddish on the younger.

The main portion of the stem consists of wood, or xylem, with prominent wood rays and water-carrying vessels, or ducts (Fig. 18). The wood is somewhat soft and rots quickly. Stalks turned under by a breaking plow rot and disappear within a few months. Cotton stalks may be macerated and the material obtained used in making paper.

**Leaves.**—The leaves on various species of cotton vary greatly in size, shape, texture, and hairiness. Some have leaves that are

nearly smooth, or glabrous, whereas others, such as *G. obtusifolium*, Roxb., have decidedly hairy leaves. The leaf blade of most species is rather thin and papery, but some have thick leathery leaves. The size and the shape vary considerably on an individual plant; the range is much greater, however, on different species. Most varieties and species have leaves with five more or less well-defined lobes (see Fig. 1), but the actual shape ranges from a rounded entire leaf, *G. sturtii* of Australia, to the deeply cut leaves of the okra-leaved strain of the King

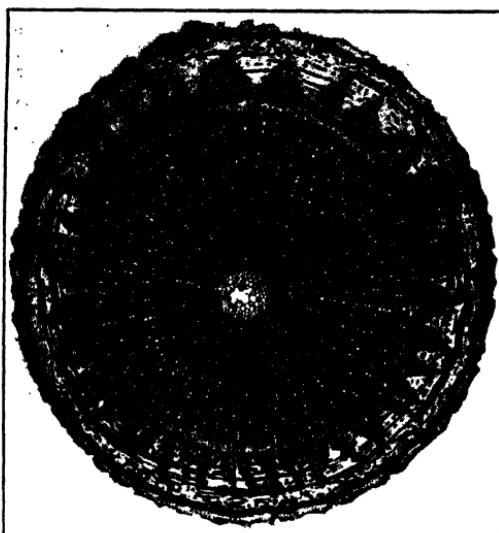


FIG. 18.—Enlarged cross-section of stem of mature cotton plant. (After Stanford and Vichocer.)

variety of *G. hirsutum* (Fig. 15e). Many of the Asiatic varieties have deeply cut leaf blades, of which *G. arboreum* (Fig. 1a) is a good illustration. Okra-leaved plants have appeared in several different varieties of American Upland cottons, *viz.*, King, Express, Delfos, Acala. These are probably either mutants or reverersions. On the under side of cotton leaves are three to five prominent veins. Numerous branches from these ramify through the leaf. A small, shallow, cup-shaped nectary is usually found on the midpart of the largest vein, and in some instances similar nectaries are found on two of the other larger veins.

**Roots.**—The main stem of a cotton plant is continuous with the main root, which is known as a tap root. The transition

takes place about the surface of the ground. The tap root has a proportionately thicker cortex, and the wood tends to arrange itself in a four-angle structure, with four more or less well-defined ridges showing on the outside. The branches that arise from the tap root are irregularly grouped in rows. The complete number of rows is four, but, because of twisting and irregularities, often not more than three can be recognized. Two of the rows of branches stand at right angles to the other two.

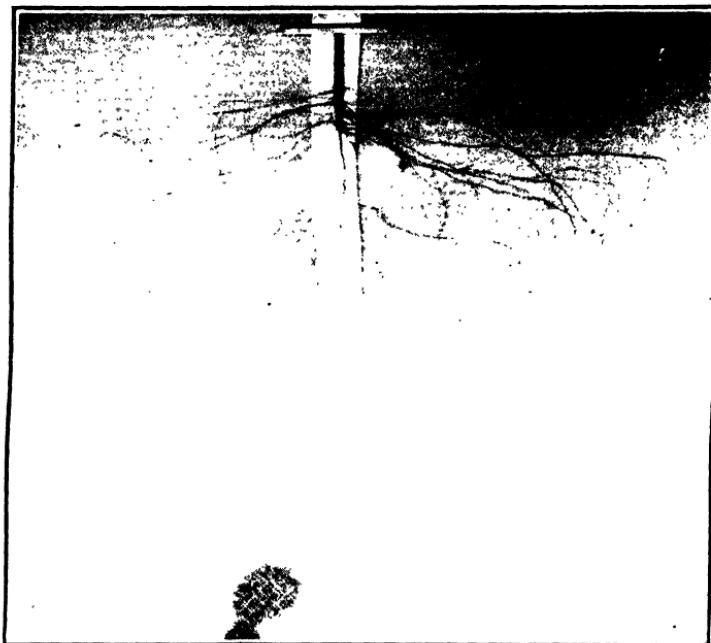


FIG. 19.—Root system of a cotton plant.

The tap root tapers rather rapidly. A foot beneath the surface of the ground it is no larger than the secondary branches. Two feet beneath the surface it has a diameter of about  $1\frac{1}{16}$  inch. This slender root grows downward for a distance of several feet without diminishing in size appreciably. The depth reached probably depends, to some extent, on the texture of the soil and its moisture conditions. On Deer Creek silt loam land, the writer assisted by C. A. Tate, dug out the root system of a plant of Express cotton, an Upland variety (Fig. 19). The end of the tap root died at a depth of 28 inches, but two laterals that arose just a short distance back of the tip pursued their course downward,

one of them reaching a depth of 5 feet 11 inches. In their course these roots passed through several layers of rather dense soil. These caused them to thicken somewhat and to pursue a slightly zigzag course, but they were not turned nor stopped. Balls<sup>4</sup> says that the resistance offered cotton roots by soils of normal texture is negligible. In so far as the writer is aware, no one has dug out the root system of a cotton plant growing on tough buckshot or clay soil; so it is not known how well the roots can penetrate that type of soil.

Balls<sup>4</sup> dug out the root system of a plant belonging to one of the Egyptian varieties, and found that the tap root penetrated the soil to a depth of about 7 feet 4 inches, where it was checked by soil saturated with water. This plant was grown in Egypt under irrigation. King<sup>5</sup> traced the tap root of a plant of the Pima Egyptian variety to a depth of 10 feet 8 inches. This plant was grown in Arizona under irrigation.

*Root System of an Upland Variety of Cotton.*—The root system (mentioned above) dug up by Mr. Tate and the writer on Sept. 15 belonged to a plant of the Express variety that was planted Apr. 7. There was no rain from June 1 until the time of the digging. The land was a silty loam of medium fertility. The plant was treated with nitrate of soda at the rate of about 300 pounds per acre, and was carefully cultivated.

There were no roots in the upper 5 inches of soil. This condition was probably influenced by the dry weather. Other years, during rainy periods, the writer has seen numerous cotton roots appear above the surface of the ground. Beginning at a depth of about 5 inches, twenty-one laterals sprang from the main root within a space of about 10 inches. These laterals, several of which were large, radiated outwardly and slightly downward. Some of them were cut off in digging a trench about the plant 4 feet from the main root. Many branches sprang from the large laterals, and some of them grew downward. The main laterals did not appear to turn downward except in a few instances, and it is possible that in these cases the root running downward was a branch at the tip of the root rather than the main root itself. For a space of a few inches below the origin of the large laterals there were no large branches. Then below this point within a space of about 10 inches several rather slender laterals were given off. Below a depth of 28 inches there were very few branches arising from the few roots which

reached that distance from the surface. Branches given off by laterals branched and rebranched until there was a network of fine thread-like roots running throughout and ramifying every inch of soil in a block more than 8 feet in diameter and  $2\frac{1}{2}$  feet in thickness. Below this block, or in the lower masses of soil reached by the roots, but very few branch roots were found and it is doubtful if these functioned extensively. Balls<sup>4</sup> found that, in the Egyptian plants which he studied, the slender roots that grew down to the lower depths of soil there branched freely where moisture was found. They doubtless functioned normally.

*Root System of Young Plants.*—The root system of young plants develops rapidly and is surprisingly extensive. Balls<sup>4</sup> found that a seedling plant 7 days old had a total root length of 20 centimeters; one 14 days old, 2 meters; 3 weeks old,  $4\frac{1}{2}$  meters.

The following table from Balls<sup>4</sup> gives the depth length of roots of Egyptian cotton plants dug up at successive dates during a season. These plants were growing in a field.

	LENGTH OF THE ROOT, CENTIMETERS
Sown Mar. 28.....	0
Measured Apr. 2.....	6
Measured Apr. 4.....	14
Measured May 15.....	55
Measured July 1.....	140
Measured Sept. 1.....	220

**Flowers.**—About six or eight flower buds are produced on each fruit limb, one arising at each joint. Unusually large plants may have many more. The buds appear at first as small, pyramidal-shaped green structures, and are known as squares (Figs. 16 and 20a). Each square consists of three triangular-shaped leaflets known as bracteoles, or bracts, and the flower bud proper. The bracts completely enclose and protect the tender, growing flower parts. Flowers open about 21 days after the squares are first recognizable. The first flowers to open are low on the plant and near the main stem; the next are farther out on the branches or higher on the plant, the succession being both centrifugal and acropetal.

A flower bud that is to open the following day may be recognized by its enlarged but well-twisted corolla (Fig. 20b). Flowers used in hybridizing work are opened and emasculated when in

this stage. Figure 20a shows the large showy open flowers. They are somewhat bell-shaped and have a spread of about 2 inches. When it first opens, the corolla, which is the most

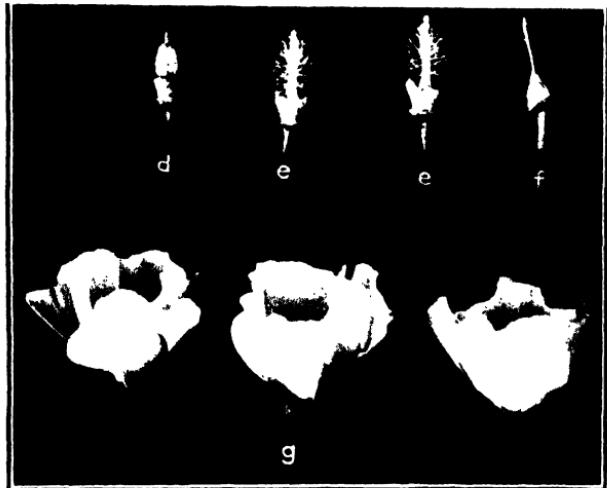
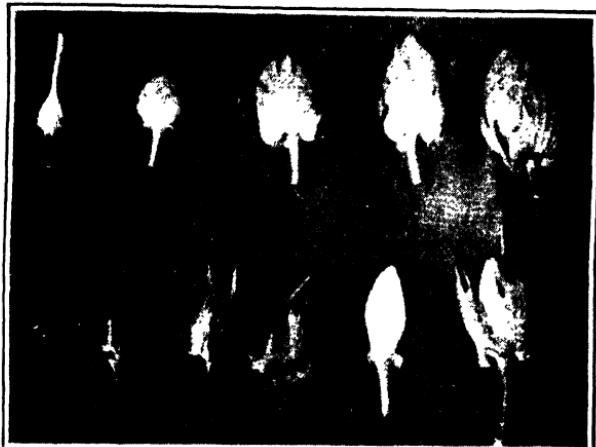


FIG. 20.—Flowers, flower parts and developing bolls: (a) squares; (b) flower bud just before flower opens, bracts removed; (c) flower bud, bracts not removed; (d) flower with corolla removed showing stamens and pistil; (e) like d except that anthers have shed pollen; (f) pistil after other flower parts have been removed; (g) open flowers; (h) to (l) stages in development of bolls.

conspicuous part of the flower, is creamy white to a deep yellowish-cream color in American Upland varieties, but toward the

close of the first day it turns to a pinkish color. The second day it is an attractive red color; the third day it withers and usually falls, taking with it stamens and the upper part of the pistil. Flowers of some foreign species are deep yellow when they open; others are a brilliant red.

The parts of a flower as they succeed each other from the outside inward will now be studied (Fig. 21). First is the whorl of three green bracteoles, or bracts, which have been mentioned. Inside of this is an inconspicuous green ring, the calyx, with five more or less well-defined irregular lobes, the sepals. Inside the calyx is the corolla, which consists of a whorl of five petals united at the base. Inside the corolla and attached to it at the

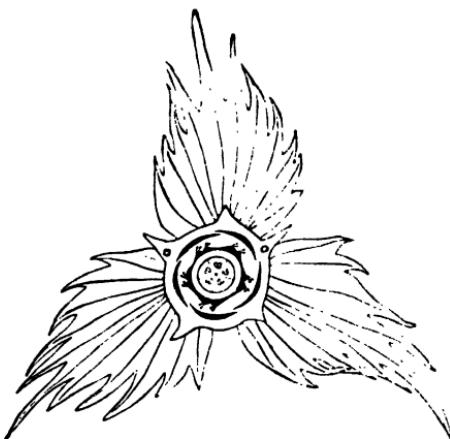


FIG. 21.—Diagram showing relation of parts in a cotton flower. (After Cook.)

base is a whorl of numerous stamens. The stamen filaments are united below to form a tube which surrounds the pistil (Fig. 20d). The anthers, on the outer end of the free part of the stamens, appear to be in ten more or less well-defined rows. The stamen tube shows ten ridges. The pistil consists of a small conical ovary (Fig. 20f), a slender thread-like style, and a stigma. The stigma appears to be simply the outer end of the style slightly enlarged, grooved or lobed, and covered with a stigmatic surface, which is receptive to pollen grains. There are as many lobes, or branches, at the tip of the stigma as carpels in the ovary or locks in the resulting boll. The pistil in Upland varieties is formed from four or five carpels; in Egyptian and Sea Island, from three, as a rule.

A cotton flower also contains nectaries, which will be discussed later. Some species have some rudimentary structures about the base of the calyx, the morphological significance of which is not well understood. Further details of floral parts will be given in Chap. VI.

**Cotton Bolls.**—The ovary enlarges, ripens, and makes a pod, or capsule, which is known as a cotton boll. Different stages in the development of boll from ovary to maturity are shown in Figs. 20*h* to *l*. A young boll enlarges rapidly and grows to full size in a comparatively short time, but a considerable period further elapses before the boll is ripe, or ready to open. The seeds and lint within require time to develop and mature. The length of time between bloom and open boll ranges from about 45 to 65 days, varying to some extent with the variety, but more with climatic conditions, or with the time of the season the boll is developing. Less time is required during the warm weather of summer than during cooler temperature of the fall.

The size and the shape of cotton bolls differ greatly with different varieties. The variation in different species is even greater. Forty to fifty bolls of the largest-bolled varieties, such as Triumph and Lone Star, will make a pound of seed cotton, whereas from 80 to 110 bolls of the smaller-bolled sorts may be required. Most of the long-staple varieties have small bolls. The bolls are somewhat larger and there are more bolls per plant on plants grown on rich land where there is plenty of moisture. On average land there are not more than eight or ten per plant. Bolls with five locks yield slightly more seed cotton per boll than bolls with four locks.

When the boll is ripe, the capsule cracks or splits along the lines where carpels meet, and the cotton within expands greatly, pushing out beyond the walls of the capsule, or burs as they are called, in a white fluffy mass (see Fig. 22*a*). It is desirable that the locks cling together slightly as in the boll shown in Fig. 22*a*. This facilitates picking, for bolls of this type can be picked at one grasp. The lower end of each lock is wedged in between two adjacent parts of the bur firmly enough to support it. The most satisfactory boll has the locks wedged tightly enough to keep them from falling to the ground, but they are not so securely fastened but that they may be pulled out entire. Each lock (Fig. 22*c*) maintains its identity or holds together because of the interlocking of its numerous fibers, which are attached to and

surround the several seeds contained. Figure 22*d* shows seeds with lint attached. The lint fibers have been combed out straight. Figure 22*e* shows lint fibers after removal from seeds. Each fiber is the outgrowth of a single epidermal cell of the seed coat (for more complete discussion of cotton fibers see Chap. VII).



FIG. 22.—Open cotton boll and boll parts: (a) boll; (b) empty burs; (c) locks; (d) seeds with lint attached; (e) lint; (f) seeds.

The fibers shown in Fig. 22*e* are  $1\frac{1}{8}$  inches in length and are considered long-staple. Excepting Meade, the staple of long-staple American Upland varieties ranges in length from  $1\frac{1}{8}$  to  $1\frac{3}{8}$  inches. The greater quantity of this kind of cotton is  $1\frac{1}{8}$  to  $1\frac{3}{16}$  inches. Meade is an Upland variety with a staple similar to that of Sea Island. The staple of both of these varieties averages about an  $1\frac{1}{2}$  inches in length, but some strains have

considerably longer staple. Short-staple Upland varieties have staples ranging in length from about  $\frac{3}{4}$  to  $1\frac{1}{16}$  inches.

**Storm Resistance.**—The open bolls of some varieties of cotton hold the cotton well during storms or periods of rainy, windy weather. They are said to be stormproof. These varieties have moderately firm locks that cling together well; they have a bur that is stiff and on opening it assumes a cup-like form which will support and hold together the locks; the bolls tend to hang down, so that the bur serves as a roof over the locks and rain water drains from the locks thoroughly; the lower tip of each lock is held rather securely between adjacent parts of the burs.

The bolls of some varieties do not open wide enough for the cotton to project from the boll. The burs of others are so twisted that the cotton is held very securely. In still other cases the cotton is "tight in the boll," the lock being grasped so firmly at the base of the boll that it cannot be pulled from the boll except in pieces. All these types are stormproof in a sense, but the last three are not satisfactory on account of their bad picking qualities.

Certain varieties are weak in storm resistance because the bur is thin and its divisions or fingers bend back so far after the boll opens that the locks are not supported or held securely. The lint of these varieties is usually soft, silky, and somewhat sparse on the seeds. The locks are not firm, but stretch out and dangle in the wind.

**Cotton Seeds.**—Cotton seeds are irregularly pyriform in shape and approximately  $\frac{3}{8}$  inch in length (Fig. 22f). The size varies considerably with different species and varieties, the range being from about  $\frac{1}{4}$  inch in length for the smaller to nearly  $\frac{1}{2}$  inch for some of the larger-seeded sorts. Duggar<sup>1</sup> considers seed of Upland cotton large if 100 seeds weigh 13 grams or more; medium, if 100 seeds weigh 10 to 13 grams; and small, if 100 seeds weigh less than 10 grams. A bushel of average-sized seed contains about 120,000 seeds.

The legal weight of a bushel of cotton seed varies in different states. For fuzzy-seeded Upland cottons the range is from 30 to  $33\frac{1}{3}$  pounds. Much of the seed sold at present is sold by the 100 pounds, or in 100-pound sacks, and no mention is made of bushels. For smooth-, or "slick—"seeded cottons, like Sea Island, 44 to 46 pounds are required to make a bushel.

**Fuzz and Linters.**—In most Upland varieties, after the lint is removed there remains about the seed a woolly covering of short

fibers, which is known as fuzz (see Fig. 22f). These are also epidermal hairs, produced by the outgrowth of epidermal cells. They differ from the lint fibers in being much shorter, under  $\frac{1}{16}$  inch as a rule, and in being more or less colored. Lint is usually white in color, but the fuzz, or *linters* as that portion of the fuzz removed by seed-delinting machines is called, is frequently a greenish, brownish, or tawny color. Sea Island, Meade, and a few other Upland varieties have no fuzz except a small tuft at the pointed end of the seed. Occasionally, a degenerate plant is found without lint or fuzz on its seeds.

*Seed Structure.*—Surrounding the seed proper is a stiff, tough, dark-brown covering, which is designated as the seed coat. This, if examined closely, especially during its development, shows two distinct layers that come from the integuments of the ovule, and

one or two membranous or papery layers that have come from endosperm and nucellus of the ovule. Examined microscopically, there appears on the outside of the coat a well-defined epidermal layer among the cells which are the lint and linter hair cells. Under this are layers of pigment-bearing cells more or less compressed and crushed. Next comes a single layer of very thick-walled cells, which terminate the outer layer of the seed coat. Next toward the inside of the seed is a single layer of greatly elongated cells, the palisade cells. They have thickened walls and make up about half of the entire



*Longitudinal section of a cotton seed embryo. (After Stanford and Viehoever.)*

of the palisade cells are the remains of several layers of collapsed thin-walled

cells. These in the mature seed coat are pigment-bearing. They mark the inner limit of the seed coat proper. Between the seed coat and the embryo are fragments of the nucellus and endosperm of the ovule. They appear as a very thin, brownish, papery layer.

The embryo, shown in longitudinal section in Fig. 23, makes up almost the entire kernel of the seed. It consists of two seed leaves, or cotyledons, and a small sprout, or caule. The cotyledons are large, comparatively thin, and much folded and twisted about the short cylindrical caule. The cotyledons are well

filled with rich food, which is used by the young plant after germination. The embryo is nearly homogeneous in structure except for numerous oil glands that appear as dark dots throughout the cotyledons and the upper part of the caule. The lower portion that makes the radicle, or root, contains no glands.

**Young Plants.**—As the seed germinates, the caule of the embryo enlarges and lengthens rapidly. The lower end develops the radicle, or primary root, which pushes its way out through the micropyle of the seed and rapidly plows its way downward in the soil. The portion of the caule between the radicle and the point of attachment of the cotyledons develops a



FIG. 24.—Young cotton plants two or three days after germination. Cotyledons are very prominent.

primary stem or hypocotyl. This stem enlarges and lengthens rapidly, becomes arched, and the top of the arch pushes its way upward and out of the ground. A day or so later, if conditions are satisfactory, the arched hypocotyl straightens out. This lifts the cotyledons and growing tip of the stem above the surface of the ground. Figure 24 shows the appearance of plants a few days old. The bud forming the stem tip between the cotyledons rapidly enlarges and unfolds, forming the stem proper, branches, and leaves.

**Nectaries.**—Cotton plants have two types of glands, external and internal. The external glands are known as nectaries. There are four sets of these, one inside the flower and three extrafloral. The number and the development of the extra-

floral vary considerably in different species. The floral nectary forms a ring about  $1\frac{1}{16}$  inch wide on the inside of the calyx near its base. The secretory part of the nectary consists of numerous pluriseptate glandular hairs, or papillæ, closely aggregated (Fig. 25). These papillæ, according to Stanford and Viehoever,<sup>6</sup> are developed from modified epidermal cells. The floral and other nectaries excrete a sweetish liquid, which attracts bees, butterflies, and various other insects.

A second set of nectaries is found on the outside of the calyx near its base. This set consists, as a rule, of three irregularly triangular-shaped nectaries.

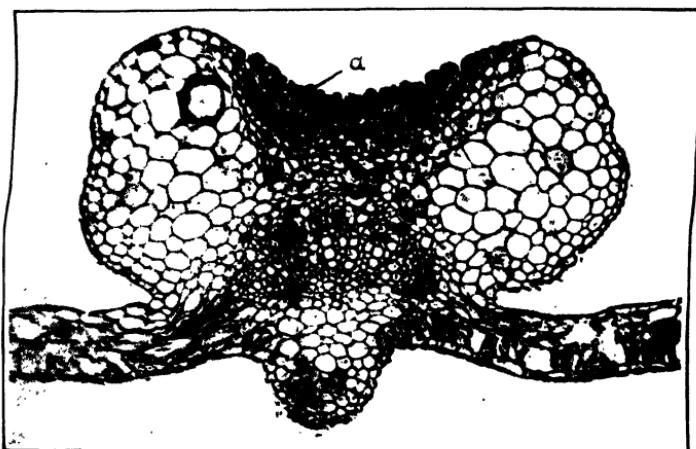


FIG. 25.—Section of cotton leaf and leaf nectary. (a) Glandular cells of nectary.

A third set consisting of three nectaries is situated on the pedicel of the flower, one being near the point of attachment of each bract. These nectaries are prominent. A part of the extrafloral nectaries may be lacking on early flowers.

On the large veins on the under side of foliage leaves is the fourth set of nectaries. There is usually one on the midpart of the largest vein, and very frequently two others are in similar positions on the two other large veins of the leaf. Figure 25 shows a section through a leaf nectary.

The quality of the nectar from different nectaries may differ to some extent. It has been observed that bees visiting extrafloral nectaries do not go to the ones within the flowers.

**Internal Glands.**—Internal glands are found in all species of cotton plants and are thickly distributed over the entire plant,

except the root, which does not have many. They appear as small dark specks (Fig. 23), and are known as black glands, oil glands, resin glands, etc. Each gland, according to Stanford and Viehoever,<sup>6</sup>

. . . . consists of an oblate or spheroidal central sac 100 to 300 microns in diameter, filled with a more or less homogeneous yellow or brownish secretion, surrounded by an envelope of one or more layers of flattened cells, which in the glands exposed to light contain a red pigment.

The glands exposed to light have anthocyan in the border cells, and the secretion within the gland contains resins, ethereal oil, quercetin, and perhaps tannins. Glands that are not exposed to light have no anthocyan in their border cells, but the glands contain a toxic or poisonous compound known as gossypol.

It seems very probable that the function of the nectaries is to attract insects to the plants, but the function of the internal glands is not so evident. It has been conjectured that the substances in these glands, or at least most of them, are excretions useless to the plant, since they tend to remain in the glands indefinitely without change. Stanford and Viehoever<sup>6</sup> suggest that the changes in the gossypol which occur with the unfolding of the cotyledons may indicate its usefulness in the metabolism of the young seedling, and the pronounced toxicity of gossypol in the seed may be a protective adaptation against animal attack.

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## CHAPTER V

### PHYSIOLOGY OF THE COTTON PLANT

Only a limited amount of research work has been done on the physiology of the cotton plant; consequently, there is a scarcity of data. The most extensive work is by W. L. Balls in Egypt. He used Egyptian varieties mainly in his experiments, and the cotton was grown under irrigation. This was an advantage, in that one of the main environmental factors, water supply, was under control; but results obtained under such conditions may not apply to American cottons in some cases.

**Water Relations.**—All living plants must be permeated by water. It functions in the solution and transportation of products of metabolism, the transportation of mineral nutrients from the soil to the plant, and its elements, hydrogen and oxygen, are made use of in nutrition.

*Water Absorption.*—Except for the enlarged portion of the tap root of cotton plants, the roots are very slender and inconspicuous; so much so, in fact, that it was not realized until comparatively recently that cotton is really a deep-rooted plant. When plants are pulled up, the smaller laterals and tap root are broken off so near the point where the root joins the stem that they appear to have been shallow-rooted. Balls,<sup>2</sup> King,<sup>5</sup> and some others excavated about cotton plants and tediously picked the soil away from the roots of a number of plants, so as to determine their extent and course. It has been found that the tap root, where conditions are favorable, sometimes penetrates to a depth of 10 feet, and that the laterals, which are numerous, run outward for a distance, governed probably by the closeness of other plants, and thence downward almost as far as the tap root. The roots thus course very thoroughly through a large volume of soil. The larger the volume of soil available the larger the root development and the greater the plant's power for absorbing water and nutrient minerals. Other things being equal, this, of course, results in larger plants.

Although the tap root and the main laterals are for the most part small in diameter, they function actively. Each contains

a few large vessels through which water moves freely, a quart or more being carried during a day's time.

While the plant is small, it can absorb water only from the upper layer of soil but as the root system develops, it draws its supply from the store deeper in the ground. The upper laterals die after a time and new ones are grown farther down in the soil. During the dry weather of August and September, most of the water is drawn from sources several feet deep, unless there is a hardpan, or impermeable layer, near the surface.

The amount of soil water available is an important factor in the growth of cotton plants. A scarcity immediately checks growth, but if the scarcity is not too prolonged, a watering will revive the plants and quicken them into activity anew. An excess of water, as water-saturated soil, asphyxiates the roots and stops the growth of the whole plant. The rise in the water table or water level in the soil has done a great deal of damage to the cotton crop in Egypt. In 1909, it was estimated that the loss was equal to one-third of the crop.

Within certain limits there is probably a close relation between water supply and the length and strength of cotton fibers; Balls<sup>1</sup> is of the opinion that a single irrigation may have considerable effect.

*Transpiration.*—The amount of water evaporated from or given off by a field of large cotton plants in course of a day is enormous. Balls<sup>1</sup> has estimated the loss for Egyptian cotton, grown in Egypt, to be 50 tons per acre per day, or 3 pints per plant. Ridgeway, in Alabama, and Lloyd,<sup>4</sup> in Arizona, obtained results showing somewhat less amounts lost. The water loss from the Egyptian plants was greater than the total amount supplied the land in irrigation. The difference was made up by ground water.

This heavy loss of water is due to the excessively large amount of evaporating surface exposed by the leaves in a field of cotton. When the stomata are open, the transpiring surface exceeds many times the area of the field.

One function of this transpiration current of water is to carry mineral nutrients from the soil to the various cells of the plant, where they are used in building up foods. Another function, one of much importance to cotton plants growing in hot, dry regions, is the cooling effect produced by the evaporation of water from the leaves and other parts. As has been shown in another place, this cooling effect reduces the temperature of

cotton leaves several degrees. Lloyd<sup>4</sup> and Balls<sup>2</sup> have both shown that excessive loss of water causes cotton plants to stop growth temporarily, even if it is not sufficient to cause water stress or wilting.

It is a difficult matter to determine accurately what amount of water is actually lost by cotton plants through transpiration when they are growing under normal conditions. Various methods have been devised, as cutting off a stem and immersing the cut end in a volume of water so arranged that the amount taken up can be measured; and growing plants in pots and weighing the pots and plants frequently to determine losses. These methods are objectionable in that the plants are not in normal condition when study is made, or are not grown under normal conditions. A plant in a pot does not have a chance to make normal root growth, and one plant by itself is subject to stronger air currents and a drier atmosphere than a plant in a field. Probably the most accurate way is to make a series of successive weighings of a leaf of known area soon after it is removed from the plant. The weighing should be done among the plants in the field where the humidity of the atmosphere is normal. Ridgeway, in Alabama, reported by Lloyd,<sup>4</sup> measured a loss of 5.25 grams per 100 square centimeters per hour. The rate will, of course, vary greatly with environmental conditions. Lloyd observed that in Arizona under severe environmental conditions, there was a checking of transpiration about 9 a.m., but that in Alabama, under less severe conditions, it was later —11 a.m. to 1 p.m.

*Relation of Water and Dry Matter Produced.*—Photosynthesis and the elaboration of organic compounds begin in the leaves of cotton plants soon after sunrise, if light and temperature conditions are favorable, and continue until the roots have so reduced the supply of water available in their immediate vicinity that there begins to be an insufficiency in the plant. This causes the stomata to begin to close, and soon after there is a stoppage of photosynthetic activities in the leaf. The time at which this occurs varies considerably, depending on the wetness of the soil and the humidity of the atmosphere, but it is normally between 9 a.m. and noon. The plants are gaining in weight of dry matter only when new organic materials are being built up.

The field water requirements of cotton plants may be indicated by dividing the total weight of water lost by a given area during

the season by the dry weight of the plants produced on the same area. In experiments conducted by King<sup>5</sup> with Egyptian cotton in Arizona, from 4,013 to 5,426 pounds of dry matter per acre were produced, the amount varying with different plats. The plat which received the most water made the most dry matter, but the percentage of dry matter for amount of water lost was smaller than that of a plat that received less water. Plat 1 used 4,855,184 pounds of water per acre and made 5,426 pounds of dry matter, the field water requirement being 894.8. Plat 3 used 3,425,296 pounds of water per acre and made 4,013 pounds of dry matter, its field water requirement figuring 853.6.

*Effect of Water Supply on Flowering and Fruiting.*—It was shown on a preceding page that there is a close relation between the growth of cotton plants and their water supply. All conditions being favorable, an increase in water, up to a certain amount, was followed by an increase in growth. This increase in growth results in taller plants, more and longer fruit branches, more nodes, more flower buds, and consequently more flowers and fruit. Balls<sup>2</sup> has shown that the flowering not only follows the growth, but that if both are plotted the two curves coincide closely. Irregularities in flowering coincide with similar irregularities in growth that took place about 29 days previously. King<sup>5</sup> in his experiments with the water stress behavior of Pima cotton found that the plat to which he applied the most water produced the greatest number of flowers per plant.

*Pollination and Fertilization.*—It is a commonly accepted belief among cotton growers that, if a rain occurs during the day a cotton bloom opens, the form or boll will be shed. This opinion has some basis in fact, but the damage done by rains is not nearly so great as is often supposed. If the pollen is wetted by a rain early in the day, or before pollination has taken place, it will not perform its function and fertilization will not result. The stigma is receptive only during the first day. But the pollen is never wetted in all the flowers; some are pollinated early and some late; consequently, the rain damage, as a rule, is not great, rarely being more than 25 per cent. In some experiments made by the writer at A. and M. College, Mississippi, 13 per cent more bolls were shed where flowers were rained on in the forenoon than were shed from flowers opening the following day. Ewing<sup>6</sup> found at Holly Springs, in the northern part of Mississippi, that 15.6 per cent more bolls were shed where there was a morn-

ing rain than on the preceding and following days on which there was no rain. The shedding following afternoon rains was 6.7 per cent greater than on the preceding and subsequent days. Lloyd,<sup>4</sup> as a result of his observations of the effect of rain on open flowers, says that, at most, not more than 15 per cent of the shedding can be referred to the effect of rain. More depends on the time of the rain than on the amount.

The corolla, or bloom, of flowers that opens during rainy weather often remains attached to the flower receptacle and clings about the young boll. If it decays in this position many think that the boll will fall off, but this is probably a mistaken notion.

*Germination.*—Cotton seeds will not begin to germinate until they have absorbed a considerable amount of water—a volume equal in weight to half the weight of the seed or more. This absorption takes place rather slowly at first, because the seed is protected with a thin waxy covering which is somewhat impervious to water. The seeds will not germinate satisfactorily if kept on moist filter paper, such as is used in germinating most seeds. They must be thoroughly wetted and placed between the folds of wet cotton flannel cloth to receive sufficient water. Germination in the soil is often slow, because of the scarcity of available water in the surface layer of soil. If the soil is moist, sufficient water will be absorbed in a few days. The abundance of water furnished by a warm shower makes optimum conditions for rapid germination.

The waxy covering of the seeds serves a useful purpose in that it hinders germination of seed in the field before cotton is picked. The seed cotton in the open bolls is rained on frequently, but seeds do not sprout badly unless the rains are prolonged and are so frequent that the locks of cotton are kept wet for several days at a time. Green seeds, or seeds from bolls that have opened within the past 60 to 90 days, will not germinate well. This appears to be another natural means for the protection of seed in the field.

*Growth of Plants at Various Stages.*—King<sup>5</sup>, by irrigating plats of Pima Egyptian cotton in Arizona at different rates and measuring the height of the growing plants each week, was able to show something of the relation between water content of the soil and stem growth which may be taken as an index of the growth of the whole plant. Plat 1 was irrigated at such frequencies that

complete exhaustion of the available moisture in the upper 2 feet of soil did not occur during the period of plant development. Plat 2 was irrigated shortly before the depletion of all available moisture in the upper 4 feet of soil, and Plats 3 and 4 were given water when the available moisture in the upper 5 feet was near exhaustion. Plat 4 differed from Plat 3 in that it received an application of cotton seed meal and 16 per cent acid phosphate in the drill at the rate of 500 pounds per acre. The proportion of each constituent in the fertilizer is not given. Figure 28 shows the percentage of soil moisture at different periods and the corresponding growth responses in King's experiment.

Plats 1 and 2 were irrigated on June 10, and for this reason the plants on these plats made more rapid growth throughout the rest of June than did the plants on Plats 3 and 4, which were not irrigated until June 26. Throughout July and August the plants in Plats 1 and 2 continued to grow more rapidly and appeared to be more luxuriant. It was observed during periods in the summer, when temperatures were high and transpiration was at its greatest, that plants on Plat 1 wilted more than the plants on any other Plat.

It is a matter of common observation that plants grown during a season of moderate rainfall are more luxuriant than ones grown during a dry year. Texas cotton plants are considerably smaller than the ones grown in the Mississippi Delta. Difference in water supply is the main, but not the only, cause of the difference.

There is a close relationship between the root development of cotton plants and the moisture content of the soil. If the soil is saturated, root development is hindered; the roots fail to function properly and the plant soon sickens. An excess of moisture in the soil part of the time, as occurs during rainy seasons, tends to make the root system less extensive. Sufficient water can be secured by a smaller number of roots or by shorter ones. In 1923, in parts of the Mississippi Delta the root development was so poor that the plants were not anchored in the soil securely enough to make them stand erect. Wind storms blew them over badly. An unusually heavy rain fall took place that year. Dry weather favors root development. More water is needed and roots must penetrate deeply and widely to secure it.

The morphology of the root system of cotton plants is not well known on account of the difficulty in tracing it out where

plants are grown in a field under normal conditions. King<sup>5</sup> found no consistent differences between the root development of plants on the four plats, mentioned above, which he irrigated differently, except that the tap roots of the larger plants on Plat 1 were larger than those of the smaller plants on other plats, from the surface of the ground to a depth of 10 or 12 inches. Below that there seemed to be no difference, either in size, number, or distribution. The difficulties in the way of making this comparative study were so great that no definite conclusions could be drawn. It is possible, however, that the wilting or water stress exhibited by the larger plants on Plat 1 was due to their greater leaf-evaporating surface without a corresponding more extensive root system for taking up water.

With the lessening of the supply of water during the latter part of the season there is a tendency for cotton plants to stop growth, and pass into a "senescence" period, as Balls<sup>2</sup> terms it, or an old-age period of inactivity. The terminal bud first feels the influence and checks its growth; it is followed soon by terminal buds of branches and a little later by other parts. This stoppage of growth appears to be due to some internal influence which resembles the self-poisoning caused by excess heat. With the coming of fall rains in "rain countries" or with increase of water supply, as in Egypt when the Nile rises, there is often a rejuvenescence; the dormant buds awaken and grow, making new leaves, stem parts, and flowers.

Balls<sup>2</sup> found that the lower roots of Egyptian cotton plants were killed by the water if the water table rose high enough to cover them. But, following the recession or sinking of the water, new branches were sent out from the living roots higher in the soil. These new roots grew downward into the soil mass occupied by the old roots that had died.

**Temperature Relations.**—Cotton is by nature a tropical or warm-climate plant, but most of the commercial crop is grown in cooler regions. There the environmental conditions are not quite normal; consequently, special nurture must be given the plant to make it grow satisfactorily.

*Germination Temperatures.*—Cotton seed in germinators kept at a temperature of 60°F. will germinate slowly, provided moisture conditions are right. At 70 to 85°F. they germinate and grow almost normally. A complete test can be made in 5 to 6 days. If the germinator is kept at a temperature of 95 to 97°F.,

the initial growth will be very rapid, and it may be possible to get some indication of germination percentage within 2 or 3 days. But these high temperatures inhibit growth after a comparatively short time, because of, according to Balls,<sup>1</sup> an accumulation of waste materials within the plant cells. Under the high temperatures, the metabolism within the cells of the plant causes these elements to accumulate faster than they can be thrown off. Their increase results in a self-poisoning which soon inhibits growth.

In the fields at planting time soil temperatures are not apt to be high enough to cause trouble. If high temperatures do occur, they are only in the surface layer of soil and are of short duration. But it is a very common occurrence for temperatures to be too low for days at a time for satisfactory germination, or for the growth of the young plants.

*Temperature and Growth.*—The temperature at which the cotton plants studied by Balls<sup>2</sup> made the best continuous growth was

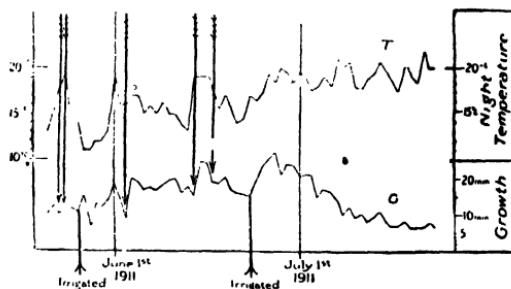


FIG. 26.—Graph showing relation of stem growth and night temperatures. The large arrows mark points where the growth was retarded by extreme heat the previous day. (After Balls.)

about 90°F.; that agrees with general observations made elsewhere. A temperature above 90° accelerates growth for a short time as was mentioned above, but it apparently fosters the accumulation of materials within the growing cells that act as a poison and retard their activity. A temperature above 98°F. for a short time checks the growth of the main stem and the effects lasts 24 hours or more. During the young and actively growing period of the plant, the rate of growth of the branches, leaves, and flowers follows closely that of the main stem. Later, under normal conditions, senescence strikes first the terminal bud or growing part of the main stem and checks its activity. The temperature and the growth of roots are controlled largely by the soil temperatures. These, for the deeper soils, are very

uniform one year with another, and rarely become high enough to injure the roots. Often, early in the season, the surface soil is cold enough to retard growth.

In common with many other plants, the cotton plant makes most growth during the night, or when the sun is not shining. Researches by Balls<sup>1</sup> showed a close relation between night temperatures and the length of growth of the main stem (see Fig. 26). Excepting the few drops in the growth curve due to the effect of extreme temperatures the day before, the two curves coincide

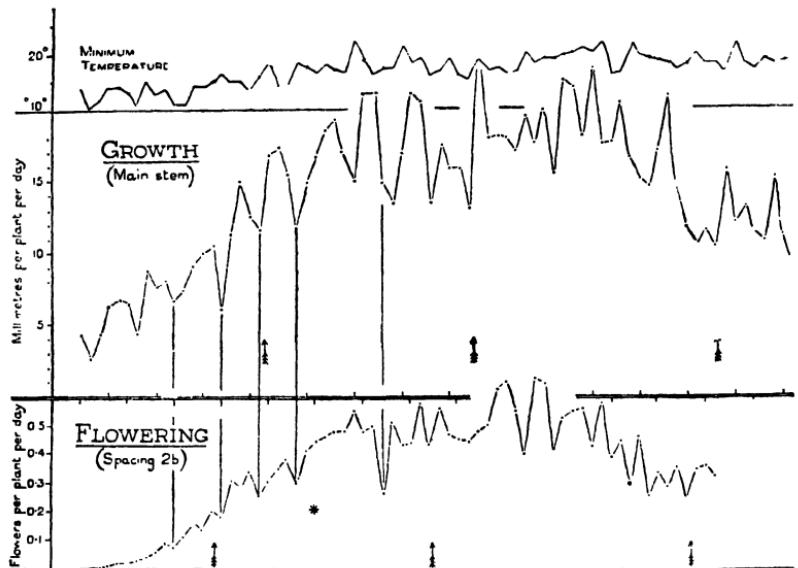


FIG. 27.—Graph showing relation of growth of main stem and flower production.  
(After Balls.)

almost perfectly until the first of July, a period of more than a month. After this time certain inhibiting factors disturb the close relation between the two. Balls<sup>2</sup> figured a correlation of  $0.7843 \pm 0.0459$  between length of growth of main stem and minimum night temperatures, if the daily periods where the maximum temperature had risen above  $36^{\circ}\text{C}$ . were excluded. With these periods included, the correlation was  $0.5236 \pm 0.0755$ .

*Temperature and Flowering.*—It is a matter of common observation that cotton plants fluctuate widely in the number of flowers produced from day to day. Several environmental factors have a bearing on this phenomenon, and it is a difficult matter to determine the relative value of each, since the effect follows the

cause by a period of several days or even weeks. Young squares or flower buds on Mississippi Upland varieties may be recognized 20 to 23 days before the flower opens. Their primordia existed some days in advance of this. Probably they are more susceptible to the effect of environmental influences when very young than at any other time. Balls<sup>3</sup> found that there is a close relation between the number of flowers produced on any given day and the growth of the main stem of the plant on a corresponding day 29 days previous (see Fig. 27). Temperature influences the growth of the stem immediately, as has just been shown. Consequently, flower production seems to be influenced by daily temperatures about 29 days previous.

*Tissue Temperatures.*—The temperature within the tissues of young leaves and the younger parts of stems is usually below the shade temperature of the surrounding locality, the difference being in some instances as much as 10°F. The temperature of old leaves, on the other hand, is usually higher than the local shade temperatures, ranging, according to Balls,<sup>2</sup> from 5.4°F. below to 18°F. above. The rapid evaporation of water from the younger tissues tends to keep their temperature lower, but as they become older this regulatory power is largely lost. Water shortage in the soil will also cause a loss of this power. Evaporation from the leaves will be reduced if there is a scarcity of water about the roots. The closing of the stomata of a leaf will cause a partial or total loss of the thermoregulatory power in young leaves. This, according to Balls,<sup>2</sup> may result in a temperature increase ranging from 0 to 9°F.

*Light Relations.*—The cotton plant is generally considered a sun-loving plant and thrives best in the "sunny South" of the United States and in other countries which have abundant sunshine.

*Sunlight and Growth.*—Although it may seem strange, since cotton plants require abundant sunshine for satisfactory growth, recent research has shown that direct sunlight inhibits temporarily the growth of the plant. Photosynthesis and other physiological functions continue, of course, in the presence of sunlight and cannot go on without it. Lloyd,<sup>4</sup> experimenting with cotton plants in Alabama, found that there was not only a cessation of growth during the hours of sunshine, but a shrinking of stem and leaves. Leaves accurately measured showed 10 per cent less area. Balls,<sup>2</sup> working with Egyptian cotton, secured similar

results. He proved that the growth inhibition apparently due to sunlight was directly due to a water shortage. He placed glass bell jars over plants in sunlight and found that their growth continued. The bell jar kept a humid atmosphere about the plant. He observed further that, if one-fourth of the lower leaves of the plant were removed, the lengthening of the main stem continued even if the plant was in sunlight. The leaf pruning so reduced transpiration that the root absorption was sufficient to supply all water losses and counteract the desiccating influence of direct sunlight. Root pruning had effect directly opposite to the leaf pruning.

*Photosynthesis.*—The work of photosynthesis is normally most active during the first part of the forenoon and continues until the stomata close. This closure naturally prevents the chloroplasts within the leaf cells from receiving an adequate supply of carbon dioxide. Balls<sup>2</sup> found that from sunrise to nine o'clock leaves increased in dry weight as a result of photosynthesis in accordance with the prevailing temperature; after that the increase was governed largely by stomatal action. The more the stomata were open during the day the greater the increase.

In reference to the amount of dry matter produced, Balls<sup>2</sup> says:

The increase in dry weight in hourly series of observations, without correction for loss by translocation, has given record values at the highest point of the curve, namely  $25(\pm 4)$  milligrams per square decimeter per hour. This rate is reached in June, between 8 a.m. and 11 a.m., when the stomata are at maximum dilatation, and the temperature is above  $30^{\circ}\text{C}$ .

It is improbable that the intensity of illumination should ever be a limiting factor in the process except before sunrise.

No definite signs of growth limitation by deficient photosynthesis have yet been discovered.

Cotton leaves have numerous stomata on both upper and lower surfaces. Balls<sup>2</sup> has estimated that for leaves of Egyptian cotton the number in the upper epidermis is 44 to 97 per square millimeter, and 116 to 176 per square millimeter for the lower epidermis. The stem and hypocotyl contain about 20 per square millimeter, and the cotyledons contain about 200 on the upper surface and 275 on the lower surface. These figures show that the average number of stomatal pores in a square inch of

leaf surface (including both sides) is more than 100,000. This immense number of pores exposes much cell surface, and consequently evaporation through the pores, when open, is considerable. A fully developed stoma is about 0.04 millimeter in length.

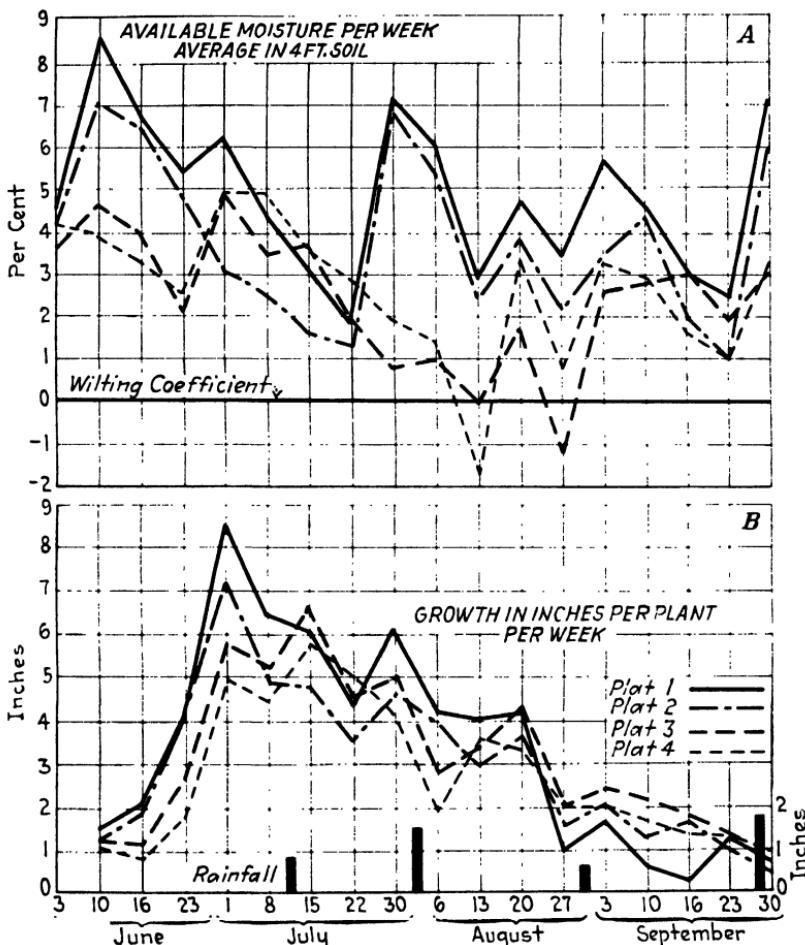


FIG. 28.—Average percentage of available moisture per week in the upper 4 feet of soil in four plats and the average increase in growth of the main stem of the plants per week. (After King.)

**Soil Relations.**—Since considerable data are given on the influence of various fertilizers and soils on the growth of cotton plants in the special chapters dealing with those subjects, it will not be necessary to enter into a lengthy discussion of the subject at this point. It is well known, however, that the cotton plants

will not make proper growth unless the soil is supplied with the common mineral nutrients in available form, and in sufficient quantity; that there must be a free movement of soil water; that the soil must contain enough organic matter to give it good water-holding capacity and permit good aeration.

*Flowering and Fruiting.*—Soil fertility is also an important factor in flower production and in fruiting of cotton plants. Observations made by Ewing<sup>6</sup> (see Fig. 29) show clearly the difference in effect that two soils within a few rods of each other have on the flowering of cotton plants. Trice cotton was planted

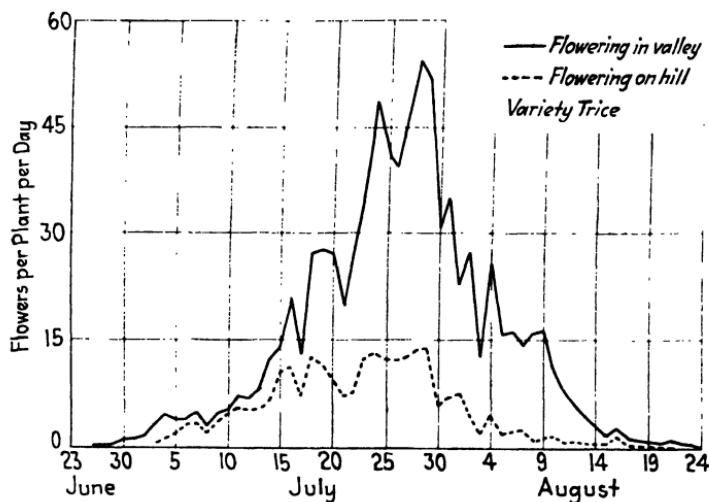


FIG. 29.—Curves showing daily range of flowering in Trice Cotton. Represented as flowers per plant day, when grown under two different soil conditions. (After Ewing.)

on fertile valley soil and on infertile soil on top of a hill nearby. On the rich soil the plants began to bloom first, bloomed longer, and produced three and a half times as many flowers in the aggregate as the plants on the hill. A high percentage of the flowers on the rich land plants made bolls. These factors account for striking differences in fruiting and yields.

Cotton plants on sandy or sandy-loam land generally fruit earlier and more rapidly than plants on clay lands. Well-drained lands also produce earlier plants. The practice of planting cotton on ridges or beds finds some justification in this fact.

The character of soil appears to have an effect on the length of boll period, or length of time elapsing between the opening of

the flower and the resulting boll. Ewing<sup>6</sup> found that for plants growing on a poor sandy hill near A. and M. College, Mississippi, the period was  $44.93 \pm 0.18$  days, while the period for plants growing on comparatively rich valley land nearby was  $48.38 \pm 0.21$  days, or a difference of 3.45 days. The plants on the high sandy land were more subject to drought. This probably caused the bolls to dry out more rapidly and open sooner. The shedding of forms and small bolls is influenced considerably by the nature of the soil, especially in its water relations. This subject is discussed at some length under the general topic of Shedding.

**Ecological Relations.** *Plants.*—Various fungi live on or within the tissues of cotton plants. They enter the roots from the soil, as does the wilt-producing fungus (*Fusarium vasinfectum* Atk.); or they enter leaves from the air, or from drops of dew or rain, as does the angular leaf-spot organism (*Bacterium malvacearum*); or they attack and penetrate bolls, even completely ruining full-size bolls, as does anthraenose or the pink boll rot, caused by *Colletotrichum gossypii*, Edg. In all instances the advantage of the relationship is on the side of the fungus. It acts as a parasite, penetrating the cotton plant and drawing its food from the organic material that the cotton plant has built up. The cotton plant gets nothing in return. Under unfavorable conditions for growth, as during cold, rainy weather, the cotton plant is very susceptible to attacks of these fungi. Serious cotton diseases may result from them.

Cotton plants will not grow wild in the American Cotton Belt as this is a region in which they are out of their natural habitat, and they cannot successfully compete with the weeds, grasses, and other plants native to the flora unless aided by man. Some planters apparently think that they can, if the amount of grass and weeds left growing in their fields be considered a basis of judgment. Clean culture and satisfactory environmental conditions are necessary for good production.

The cotton plants in a field where there is what is known as a "good stand," or a sufficient number of plants per acre to make a good yield, are in a continuous struggle with each other after the first few weeks of their existence. The roots of one plant interfere with the growth of the roots of its neighbors, and there is a struggle for the available soil water and the mineral plant nutrients which it holds in solution. A plant that has an abundance of room or that is not interfered with by its fellows, pro-

duces well as an individual, but the acre yield will be greater if there are many plants, so many that the individual is crowded and its yield reduced considerably. In spacing his plants the planter must strike the mean that will give him the greatest production. This mean varies somewhat with the season, soil, insect pests, etc., but it is fairly uniform within certain limits. The problem of cotton spacing has claimed much attention from experiment stations and at present is fairly well understood (see Chap. XIII).

*Insects.*—Cotton plants have numerous nectaries and glands which are apparently for the purpose of attracting insects, since they excrete a sweetish liquid which is sought eagerly by many different kinds of insects. Insects entering the flowers to gather the nectar from the nectaries at the base of the calyx become dusted with pollen from the anthers of the flower. Some of this pollen may be deposited on the stigma of the same flower, but a part will be carried to the stigma of some other. These insect visitors are thus effective in securing either cross- or self-pollination. Insects also visit freely the glands on the outside of the flower bracts and on the under side of the leaves, but it is not clear what advantage to the plant this is.

Boll weevils, the pink boll worms, cotton leaf caterpillars, army worms, and several other harmful insects visit cotton plants. They destroy or injure the roots, leaves, flower bud, and bolls; no part of the plant is secure against their attacks.

Boll weevils have probably been studied more than any other cotton insect on account of the great economic importance of their depredations. Certain adjustments have been observed by means of which the plants overcome the harmful influence of the weevil to some extent. For instance, the square or flower bud may be shed so soon after the egg has been deposited in it that the square will dry up and the young weevil perish before coming to maturity; or, after the egg is deposited in the square or young boll, the plant cells in the tissue about the egg may multiply or proliferate so freely that the egg is crushed before hatching. Cotton plants produce many forms—more than twice as many as can grow into bolls. With this surplus the weevil can destroy a good many without doing any real damage to the plants. If weevils are so numerous that all or nearly all of the forms are destroyed, the plant quickens into renewed growth and square production which becomes extensive if there is a continued heavy infestation of weevils.

**Life History Periods.**—The time required for the cotton plant to pass through various stages in its life history and the length of time needed for the development of different parts vary greatly with the variety, the temperature, and other environmental conditions. Data on the growth and development of a variety under one set of conditions may be of some interest and value, however. Hammond, in *Bulletin 33* of the U. S. Department of Agriculture gives data on the development of plants in South Carolina, near Augusta, Ga. The season was cool and wet. Seeds were planted Mar. 29; the first plant appeared in 14 days; enough were up in 18 days to make a stand; none came up after 30 days; the third leaf made its appearance in 8 days after the plant came up; the fourth leaf appeared the next day. The planting date in this experiment was early for the latitude. If planted later under proper moisture conditions, the periods are shorter. Under weather conditions that ordinarily prevail at planting time, most plants are up in a week or 10 days after planting, and in some cases, under extremely favorable conditions they may be up in 4 days. If the soil is dry at planting time, the seed may be in the ground for several weeks before germinating.

Plants from later plantings made by Hammond showed much more rapid growth. The average for plants coming up at different times during April was 40 days from appearance of plant to appearance of square; this varied from 34 to 45 days; for plants coming up during May the average was 29 days. Squares appearing in May, on the average, bloomed in 25 days; squares appearing in June bloomed in 24 days; August squares bloomed in 21 to 27 days, averaging 25 days. June blooms made open bolls in 45 to 56 days, or 52 days on the average; July blooms, in 64 to 71 days, averaging 65 days.

For the northern part of Mississippi, Ewing<sup>6</sup> gives growth periods as follows: flowers from 7 to 10 weeks after planting; squares or flower buds 3 to 4 weeks before the flowers open; period of development of bolls, 40 to 70 days. The fruiting period, or the time during which most of the flowers open and the fruit is set, varies considerably, ranging from 40 to 80 days. The length of the period depends on the soil fertility largely, but other environmental factors also have a bearing. The length of the boll period also varies considerably, temperature and variety probably being the chief factors influencing it. According to Ewing's observations, flowers that opened from July 18 to 31

experienced an average daily temperature of 80°F. and produced open bolls in 48 days. Flowers opening Aug. 26 to Sept. 1, inclusive, experienced an average daily temperature of 70.8°F. and required 68.5 days to produce open bolls.

**Shedding.**—By shedding is meant the abscission or dropping of forms on the cotton plant. These consist of squares or flower buds, flowers, and bolls or fruits in various stages of development. Shedding is discussed as a separate subject because of its importance as a physiological problem, the interest that it has aroused, the investigational study given it, and its economic importance.

*Mechanism of Abscission.*—The following account of the anatomical structures involved in abscission of cotton forms is quoted by Lloyd<sup>4</sup> from Balls:

The abscission layer across the flower stalk of cotton is very simple. No elaborate corky tissue is formed. A plate of cells one cell thick stretching across the stalk in a definite position, which is marked by a faint external groove, starts to divide from the periphery inwards. Each cell divides once, the two daughter cells separate instead of remaining united, and the continuity of the tissues is thus interrupted very quickly. The sole connection left is the vascular tissue of the wood, which readily breaks and the dead flower drops to the ground. The separation of the leaf is accomplished in the same way.

In consequence of this mechanism, the effect follows the stimulus very quickly . . . (Balls, 1911, p. 227) . . . The dividing wall between the daughter cells splits immediately along its middle lamella. The daughter cells which are left on the face of the scar, after the stalk has broken away, bulge outward and form a simple callus (Balls, 1912, p. 69).

*Shedding Due to Injuries.*—Injury to squares, bolls, stem, or roots of a cotton plant may cause a shedding of forms. These injuries may be due to boll weevils, or other insects, bacteria, or fungi, or they may be in the form of mechanical injuries that remove leaves or destroy roots.

Squares make response to injury, according to observations made in Alabama, by Lloyd,<sup>4</sup> throughout a period from 36 hours to 10 days. The majority fall the second day, but the high rates continue until the fifth day. Open flowers are rarely shed. Anthesis seems to inhibit abscission temporarily. Bolls may be shed in response to injury in 24 hours to 6 days. Small bolls are shed sooner than large ones, the maximum shedding being in 48 hours. Large ones are shed in from 3 to 6 days. Shedding

of squares due to boll-weevil injury takes place irregularly, ranging from 1 to 20 days, with the majority falling in about 8 days. This is probably governed partly by the location of the weevil larva within the flower bud and the part eaten first.

Ewing<sup>6</sup> found that the length of time between flowering and shedding of bolls varied considerably with the variety and with the time of season. The mean persistence period for the variety Simpkins was 6.97 days, while that of Columbia was 8.84 days. The period of persistence was longest when shedding first began and shortest at the close of the season.

*Normal Shedding.*—Much shedding of forms is due to causes other than diseases and mechanical injuries such as were mentioned above. These are of normal occurrence and are commonly considered as being caused by physiological troubles. This normal shedding is slight early in the season while plants are young, but gradually increases during the season. For a time after blooming begins, flowering is considerably greater than shedding, but later the bolls shed per day may equal or even outnumber the flowers produced. Even where there are no insects to bother, more than half of the flowers that open fail to make bolls that mature. The percentage of bolls set varies considerably with the variety. In counts made by the writer at A. and M. College, Mississippi, this ranged from 29 to 51 per cent for different varieties in the same test. Varieties like Trice, that produce a very large number of flowers, shed a higher percentage of bolls than varieties that have a smaller number. At Holly Springs, Miss., in 1914, Ewing<sup>6</sup> tagged 73,752 flowers. Only 40.31 per cent of these produced bolls. The weather and soil conditions there were very favorable and a large crop was made—more than 500 pounds of lint per acre. Balls observed 40 per cent shedding in Egypt, while Harland, mentioned by Ewing,<sup>6</sup> observed 80 to 90 per cent in St. Vincent, in the West Indies.

Most of the normal shedding affects young bolls only. Squares are shed as a result of insect injury or fungous disease, but rarely otherwise. Flowers are rarely shed.

*Cause of Shedding.*—As has been shown previously, rain during the period that cotton flowers are open interferes with effective pollination; this causes a higher percentage of the young bolls to fall on account of lack of fertilization. Hodson, mentioned by Lloyd,<sup>4</sup> showed that pollen grains burst when placed in water. Consequently, wetting pollen will ruin it. A rain during the

morning after the anthers have opened but before effective pollination has taken place may do considerable harm.

It is probable that soil-water conditions have more bearing on shedding than any other factor. Ewing<sup>6</sup> and Lloyd<sup>4</sup> both observed that there was a gradual increase throughout season. This, Lloyd considered, was probably caused by recession of water from plant roots in the deeper layers of soil. There are also minor fluctuations which are caused by daytime rains interfering with pollination and by rains causing changes in the moisture content of superficial layers of soil.

During periods of prolonged drought, when the water supply in the soil is scanty, shedding becomes excessive. Cutting a part of the roots of the plant so that the water supply is lessened causes an increase in shedding, but shading the plants after cutting the roots prevents a part of the loss. Irrigated plants shed more immediately before watering than just after. Increased shedding follows quickly if transpiration is in excess of absorption. The reduction of the water content of the plant results in the closure of the stomata; this interferes with the metabolic activities of the cells of the plant, and an increase in internal temperature occurs. Increased shedding is directly caused by these changes.

It has often been observed by planters that there is excessive shedding of forms during seasons of heavy rainfall. The excess water in the soil prevents the plant roots from functioning properly and abnormal conditions prevail within the plant. Balls,<sup>2</sup> from his studies of the cotton plant in Egypt, showed that an excessive supply of water in the soil, such as resulted from an early rise of the water table in the soil along the Nile River, may cause root asphyxiation, interfere with absorption, and thus cause shedding.

According to studies made by Ewing<sup>6</sup> and Harland<sup>7</sup>, the productiveness of soils does not greatly affect the percentage of shedding. Plants growing on good soil produce many more forms than ones on poor soil, but, on the other hand, they shed many more forms. Lloyd<sup>4</sup> offers the suggestion that nitrate of soda may be influential in lessening the loss of forms. Manures and fertilizers make plants much larger and more vigorous and increase their capacity for production.

From the middle of the fruiting season until near its close there is a heavy drain on the energy and food materials and within the cotton plant to support the growing and developing bolls. When

the plant has all the load it can carry, new forms must be thrown off. This probably accounts for at least a considerable portion of the increased shedding the latter part of the season. Observations by Ewing<sup>6</sup> give credence to this theory. He found that the removal of half the flowers that opened reduced the rate of natural shedding to 8.7 per cent. The normal loss of the check plants was 60 per cent. The flower pruning was started July 27, a time when shedding was becoming active.

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## CHAPTER VI

### REPRODUCTION IN THE COTTON PLANT

#### FLOWER DEVELOPMENT, SPERMATOGENESIS, FERTILIZATION, AND THE DEVELOPMENT OF COTTON BOLLS

Double fertilization in flowering plants was discovered only a few years ago. Since that time oögenesis and fecundation have been studied in a number of species, but only a very small percentage of the whole number has been investigated. Oögenesis and fecundation in Egyptian cotton were studied by Balls.<sup>1</sup> In so far as the writer is aware, no other species or type of cotton has been investigated, nor has Balls' work been carefully verified. There appear to be no marked peculiarities in the reproductive process in cotton.

**Development of Flowers.**—The rate of growth of cotton plants and of development of flowers varies considerably with the weather conditions prevailing different seasons, and in different parts of the same season. In the central part of the Cotton Belt, cotton planted the middle of April shows young flower buds or squares in 35 to 45 days. Cotton planted later in the season develops more rapidly. As has been shown in Chap., IV, flowers are borne on special branches, the fruit branches. Morphologically considered, the first flower bud terminates the fruit branch. Further extension is made by growth from a bud in the axil of the leaf just below. This is terminated by the next flower, and so on. From the appearance of mature fruit branches with bolls and flowers along the side, one is inclined to think they are simply lateral outgrowths.

The first step in flower formation consists in the outgrowth of a rounded lobe of embryonic cells at the tip of the stem. Next, from the sides of this first lobe, just a short distance back of the apex, there arise three other lobes. These give rise to the three bracts which grow up around the developing flower parts. A second set of lobes just within the first forms the calyx. Similar lobes within the calyx make corolla and staminal column.

According to Balls<sup>1</sup> observation, the two latter are developed nearly simultaneously. Anthers arise as small lobes on the upper part of the staminal column. The pistil, the last part of the flower to develop, is made from three to five lobes that grow up in the central part of the flower. These lobes grow together along the inner edge, each forming a hollow cone, which together form the compound ovary containing three to five cells. The tip portions grow into a beak, which lengthens into style and stigma.

The inner edge of each carpel, or the part at the central axis of the boll, forms a ridge or placenta, from which ovules arise. The ovule appears at first as a mere bulge or lobe of embryonic cells on the side of the placenta. This lobe grows

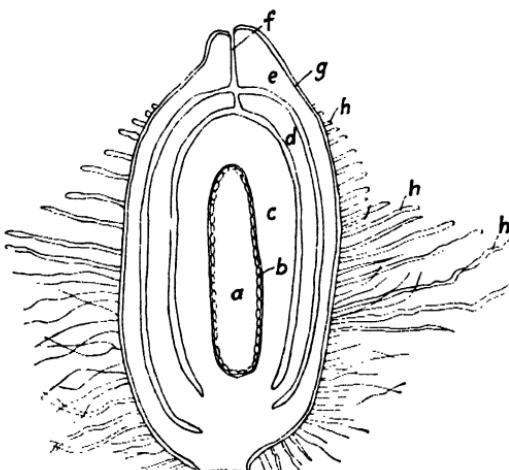


FIG. 30.—Diagram of an ovule which is developing into a cotton seed: (a) embryo sac; (b) layer of endosperm; (c) nucellus; (d) inner integument; (e) outer integument; (f) micropyle; (g) epidermis; (h) young cotton fibers of various lengths.

outward rather rapidly and forms the nucellus of the ovule, but before it has attained much size another outgrowth starts in the form of a ring about the base of the nucellus. This ring grows up around the nucellus as a protecting envelope and is known as an integument. Before the first or outer integument has surrounded the nucellus, another similar integument appears inside and just above the first and is known as the inner integument. The two integuments completely surround the nucellus except for a small opening left at its apex, known as the micropyle (Fig. 30). While the ovule is enlarging and developing its

integuments, it apparently grows more on one side than on the other, especially at the base, thus producing a curved or anatropus ovule.

**Oogenesis.**—Balls<sup>1</sup> was not able to distinguish definitely the original archesporium in the ovule, but thought it probable that a subepidermal cell near the apex of the ovule became a single-celled archesporium, and that this cell by subsequent divisions cut off about twelve cells on the side next the tip of the nucellus. The inner cell of this string becomes the megasporangium mother cell, or female mother cell that will eventually develop the egg cell or female gamete. The chain of cells between the megasporangium mother cell and epidermis multiply by lateral divisions, and thus increase the mass of cells at the apex of the nucellus. The megasporangium mother cell enlarges about the time the pollen mother cells in the anthers are enlarging, and becomes conspicuous among surrounding cells on account of its larger size, amount of dense protoplasm, and large nucleolus.

The megasporangium mother cell next probably passes through a reduction division, which results in a tetrad of cells, one becoming the megasporangium or embryo sac; but this division process has never been observed. The tetrad cell nearest the tip of the nucellus makes the embryo sac and enlarges greatly, while the other three grow no further. The nucleus of the enlarged embryo sac cell divides three times, producing eight daughter nuclei. Four of these pass to either end of the sac. Then one nucleus from each group moves toward the center of the sac, where they meet and later fuse. The other three nuclei left in the end of the embryo sac farthest from the nucellus disintegrate and function no further. The nuclei at the other end of the embryo sac are formed into cells by the aggregation of cytoplasm about them and a limiting cell wall. One of these cells enlarges more than the others and becomes the egg cell or female gamete. The other two perform no important function, in so far as is known. In this condition the embryo sac is fully developed and is ready to receive the male gametes, or, in other words, is ready for fertilization. The development of the male gametes will next be traced.

**Spermatogenesis of Cotton.**—At least four different authorities have investigated spermatogenesis in cotton. Cannon,<sup>2</sup> about 1903, studied spermatogenesis in a first-generation hybrid between Sea Island and Upland cotton. As it was a hybrid and

the material used was grown in a greenhouse, some doubts have arisen as to whether or not the phenomena observed were of normal occurrence. Recent studies by Denham<sup>3</sup> have verified Cannon's work with few exceptions. Balls,<sup>1</sup> in 1905, published a paper in which was included a description of spermatogenesis in Egyptian cotton. His description differed from Cannon's in several particulars, especially in regard to the appearance of chromosomes and their number. Balls counted twenty chromosomes as the haploid or reduced number, whereas Cannon counted twenty-eight. Denham counted but twenty-six chromosomes in the Sea Island cotton he studied. He considers that the peculiar forms observed by Balls were due to faulty fixation and doubts the correctness of the count made by Balls. Beal, of Mississippi A. and M. College, in some unpublished work on the spermatogenesis of certain Upland varieties, considers that Denham is probably correct in the number of chromosomes he gives. In the following discussion the views of Denham are followed largely.

About the time the young bracts meet at the top of the small flower bud or square, the developing anthers may be distinguished; and a week or 10 days before the flower opens the microspores or young pollen grains are to be found within the anther. (The opening of the flower takes place about 3 weeks after the bud or young square can be distinguished.) The pollen grains do not reach mature form until 2 or 3 days before the flower opens.

Portions of the subepidermal layer of cells in the young anther differentiate to form the archesporium. This archesporial layer of cells divides to form three distinct layers, the middle layer of which forms, after a series of divisions, the pollen mother cells; the other two layers form the tapetum or nurse cells. The pollen mother cells enlarge rapidly and become filled with dense, granular cytoplasm (Fig. 31). The first indication of the beginning of the reduction division of the pollen mother cell is to be seen in the contraction of the cytoplasm of the cell. This contraction results in a rounding off of the cell and its separation from the surrounding tissue (Fig. 32). The reduction division of the

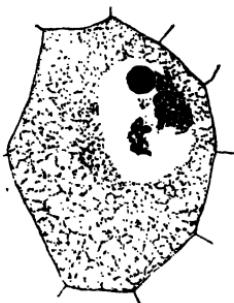


FIG. 31.—Mature pollen mother cell. (After Cannon.)

cell nucleus reduces the number of chromosomes in the cell to half the number found in ordinary vegetative cells. This is the essential step in the development of distinct male sex cells, the male gametes. These, as will be seen later, are to be found in the pollen tube of the germinating pollen grain. As the nucleus of the pollen mother cell starts to divide, it enlarges, the network of fine achromatic threads becomes more prominent, and the small lumps of chromatin on the threads enlarge. A little later these seem to break up into smaller granules which tend to locate on the network at points where threads intersect. In some plants, about this stage of nuclear division there is formed from the network mentioned a slender, much-elongated thread, parts of which appear to become paired with other portions and to fuse. This is considered by some authorities to be the combining of elements derived from each parent, elements which have been carried as separate entities in the plant cells through their numerous generations from the fertilized egg to the pollen mother cell. Neither this continuous thread nor its pairing has been clearly distinguished in cotton.

FIG. 32.—Pollen mother cell with cytoplasm withdrawing from the cell wall, an early stage of cell division. (After Cannon.)



In the next stage of nuclear division in cotton, the whole body of chromatin and thread network of the nucleus becomes massed at one side of the nucleus. This stage is known as synapsis. This mass is so dense that nothing can be determined as to what is taking place within, but it is generally thought that in this knot there is a conjugation of parental elements, and that this stage in the division is of much genetic significance. This stage of the nuclear division is of longer duration than any other. Passing from the synapsis stage there is a loosening of the synaptic knot and from it there comes a continuous thick thread or spireme, which spreads itself in a more or less looped fashion throughout the nuclear cavity. Following this, there is normally a contraction or shortening of the spireme; this is soon followed by a segmentation or breaking of the spireme into twenty-six pieces, the double or bivalent chromosomes. These are in the form of irregular loops or rings. Denham considers that conjugation has taken place telosynthetically, and that two parental chromosomes are arranged end to end in the bivalent

chromosome. Beal, of Mississippi, has evidence that the conjugation is parasympathetic.

The bivalent chromosomes are next moved to a plane across the central part of the cell; a bipolar spindle of achromatic fibers is formed, some of the fibers of which are attached to the chromosomes. The fibers of the spindle appear to shorten and pull apart the halves of the bivalent chromosomes (Fig. 33). The halves are drawn to the poles of the spindle (Fig. 34) and there disintegrate as daughter nuclei are formed. This marks the end of the heterotypic phase of the reduction division. The second or homotypic follows soon after.



FIG. 33.—Metaphase of the reduction division. (After Cannon.)



FIG. 34.—Anaphase of the reduction division. (After Cannon.)

In the homotypic division a spireme is formed which segments into twenty-six univalent chromosomes. These are moved to the equatorial plate of the cell, as mentioned; a bipolar spindle is formed and the chromosomes split, one-half of each going to each spindle pole. Here the chromosomes disintegrate, forming small granules, which are scattered throughout the two daughter nuclei formed about the poles of the spindle.

The two divisions, heterotypic and homotypic, take place in a comparatively short time. Ball has estimated that not more than twelve hours elapse between synapsis and the tetrad of nuclei.

In cotton, no cell plate separating the cells organized about the nuclei of the tetrad is formed. The cells of the tetrad are separated by furrows or constrictions that appear on the periphery of the cytoplasm, midway between the nuclei, and deepen until they meet in the center. After the formation of the tetrad

of cells, their cell walls thicken rapidly and form the elaborately figured spiny coat seen in the mature pollen grain (Fig. 35). Two or three days before the flower opens, according to Balls,<sup>1</sup> the tetrad cell divides to form a large tube cell and a small generative cell. The generative cell later divides to form two male gametes or sperm cells.

Denham<sup>4</sup> has made a study of chromosome number in thirty-two different varieties of cotton, including Sea Island, the Egyptian varieties Mit Afifi, Giza I, Giza II, and Pima; the Upland varieties Acala, Commercial I, and two Indian-American varieties; and Chinese or Indian varieties from six or more Asiatic species. The Chinese and Indian varieties were found to possess, in every case studied, only thirteen chromosomes in the reduced or haploid stage. All the other varieties investigated had twenty-six chromosomes.

**Pollination.**—As has been shown, pollen grains are produced in abundance by the numerous anthers of cotton flowers. A mature grain is spherical, spiny, has irregularly sculptured walls, and is barely visible to the naked eye (Fig. 35).

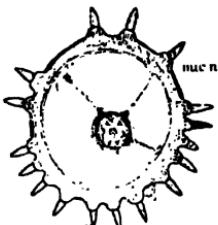


FIG. 35.—Cross-section of mature pollen grain showing spines on surface of grain. (After Balls.)



FIG. 36.—Pollen grains on stigma of a cotton flower. This was taken from an open pollinated flower. (After Kearny.)

Quantities of pollen are deposited on the stigmas of cotton flowers (Fig. 36). Most of the pollen, as is shown in Chap. X, comes from anthers in the same flower. It is deposited either mechanically or by insects visiting the flowers.

**Fertilization.**—Pollen grains germinate soon after they land in the moist sugary solution on the surface of the stigma. A tube is sent out from the grain; it enters the stigma, grows down through the central part of the style, enters the ovary, and keeps growing until it has entered an ovule. It squeezes through the micropyle of an ovule, and then plows its way through the tissue of the nucellus until the embryo sac is reached. At this point the end of the tube bursts and the two germ nuclei, or male gametes, are emptied into the sac. One of the nuclei moves to the egg cell, enters it, and fuses with the nucleus of the egg cell, thus bringing about fertilization. The other male gamete fuses with one of the two polar nuclei that have moved to the center of the embryo sac. The two polar nuclei now fuse, and there is produced a triple fusion nucleus, which is known as the endosperm nucleus. This divides to produce the endosperm of the ovule.

The growth of the pollen tube and fertilization take place in remarkably short time, when it is considered that the pollen tube must grow 2 inches or more. Balls<sup>1</sup> has observed that fertilization has taken place within 30 hours after the flower opened.

**Endosperm.**—As interpreted by Balls,<sup>1</sup> the triple nucleus, resulting from the fusion of two polar nuclei in the embryo sac and the second male nucleus, divides on the afternoon of the day following pollination. The nucleoli of the parent nuclei retain their individuality for a few divisions, showing two large nucleoli and one small one which came from the male gamete. The chromosome behavior is very irregular. Nuclei multiply rapidly and arrange themselves in a single layer in the protoplasm lining the embryo sac. The central part of the embryo sac is occupied at this time by a large vacuole filled with cell sap. Soon cell walls form between the free nuclei, beginning at the end of the sac next to the micropyle. Nuclear division and cell-wall formation continue until all the lower end of the embryo sac is filled with thin-walled cells and the young embryo is surrounded. As the embryo enlarges, it appears to digest the surrounding endosperm cells and to occupy their space. In the ripe seed the endosperm and the nucellus have so nearly disappeared that only a vestige remains—a thin papery membrane.

**The Embryo.**—According to Balls<sup>1</sup> observations, the egg cell of Egyptian cotton divides about 60 hours after fertilization is effected. The first division is at right angles to the axis of the

embryo sac. The next division is at right angles to the first. Further divisions come in rapid succession. By the time the young embryo is a week old it contains hundreds of cells and has assumed a somewhat cordate form, which indicates the beginning of cotyledons. The cotyledons grow out into broad, thin sheets, become much folded, and fill almost all the space within the seed coats (see Fig. 23).

The cells of the cotyledons of the full-size embryo contain a quantity of oil and other concentrated foods. From kernels of

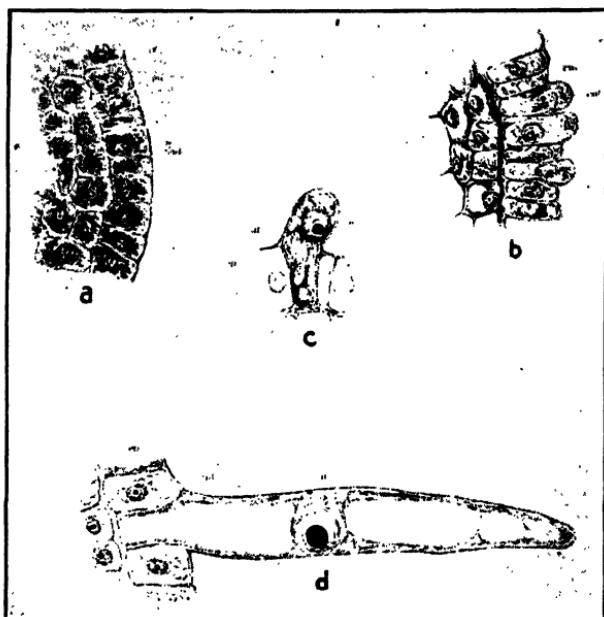


FIG. 37.—Epidermal cells on surface of young seed and early stages in the development of young fibers: (a) Undifferentiated epidermal cells (row along the right edge); (b), (c), and (d) early stages in fiber development. (After Ball.)

cotton seeds, which are principally embryo cotton plants, are obtained cotton seed oil, cotton seed meal, and other important products.

**Development of Cotton Seeds.**—When the egg cell in an ovule is fertilized by the male gamete, the ovule becomes a young seed. It is then less than  $\frac{1}{16}$  inch in length, but grows rapidly, attaining full size, or a length of about  $\frac{2}{5}$  inch, in about 20 days. The bulk of the mature seed consists of embryo. The integuments of the ovule become the seed coats. They enlarge and

thicken as the seed grows, differentiating various parts. (For details of form of embryo and structure of seed coat, see discussion of seed structure in Chap. IV.)

The epidermis of the outer integument has cells with a thick basal wall and thinner outer and side walls. The outer wall is covered with a thin cuticle. Certain of the epidermal cells bulge outward; the protoplasm and nucleus of the cell move toward the outgrowth and later enter it (Fig. 37a, b, c, and d). The outgrowth of the cell continues to grow until a length of an inch or more is attained in some instances. The longer outgrowths make lint hairs, while the shorter ones make fuzz. The development of lint and fuzz will be discussed in more detail in Chap. VII.

**Development of Bolls.**—As has been seen, the cotton boll is the enlarged and developed ovary of a cotton flower. The length of time required for the development and ripening of a boll varies somewhat with the variety of cotton and the time of the season at which blooming occurs. The maturation period ranges normally from about 45 to 65 days. During the first few days following the opening of the flower the young boll enlarges rapidly. It attains full size in about 20 days, but at this time the seeds and lint are very immature. They require almost the whole period until boll opening for complete development. In observations reported by Martin,<sup>5</sup> Lone Star cotton bolls on plants grown in Texas attained maximum size in 20 days; early bolls matured in 42.57 days, whereas, late bolls required 44.55 days. Pima cotton bolls grown in Arizona attained maximum size in 25 days, and in 1921 had a range in maturation period of 45 to 80 days. Bolls of Sea Island and Meade cottons grown in South Carolina in 1922 reached maximum size in 21 days. A mean maturation period of 57.6 days was noted for Sea Island, and a mean of 56.14 days for Meade.

It has been observed by several investigators that bolls produced during the latter part of the season require more time for maturation. This is doubtless due to the prevalence of lower average temperatures and shorter days during the later part of the cotton-growing season. In the northern part of the Cotton Belt it usually happens that there are many immature bolls on cotton plants when a killing frost comes. A part of the bolls that have not had the full maturation period will open, but their lint is more or less defective, weak, or discolored.

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## CHAPTER VII

### COTTON FIBERS

In a sense, cotton fibers are the units from which cotton fabrics are made and around which the whole cotton industry centers. A study of the structure and nature of cotton fibers is therefore fundamental.

**Development of Cotton Fibers.**—Early stages in the development of cotton fibers were traced in Chap. VI. It was shown that each fiber is produced by the outgrowth of a single epidermal cell. Until the cell bulges out on the outer side, it appears the same as all other epidermal cells. Certain of the epidermal cells produce outgrowths that continue lengthening until the long lint hair, or fiber, is made; other cells produce outgrowths which are similar to the fiber outgrowths at first but which stop growing before attaining much length. These short epidermal hairs are known as fuzz.

It appears that the production of lint hairs, fuzz hairs, or no hairs is hereditary. Certain cells must contain some hereditary principle which causes them to lengthen greatly. Others must contain a principle that causes them to lengthen to a lesser extent or not at all. Certain varieties have a low percentage of lint hairs in comparison with the number of fuzz hairs. Other varieties have a relatively high percentage of the long hairs. The percentage for any particular variety is about the same from year to year, although the environmental conditions vary.

Balls,<sup>1</sup> in his studies of the growth of lint hairs in Egyptian cotton, found that the lint cells attained full length during the first half of the maturation period of the boll—about 25 days. The cell wall remained very thin during this time, the nucleus persisted, and the diameter of the cell was about the same as in the mature hair. During the second half of the maturation period of the boll, a period of 25 days, the fiber cell wall was thickened by deposits of cellulose on the primary wall. This appeared to be put down in layers, some fibers showing as many as twenty-five concentric layers. These layers are thought by Balls to represent daily growth rings similar to annual rings in

trees. He found that the number of layers in a hair wall coincided almost exactly with the number of days cell-wall thickening had been in progress. It was thought that a thin layer was deposited during the night or early morning, but that the noon-day sun stopped the process in a way similar to the way it stopped growth of stems and branches (see Chap. V).

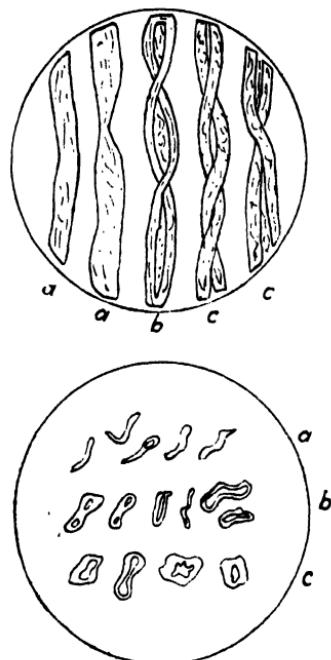


FIG. 38.—Cotton fibers in longitudinal view and cross-section: (a) unripe fibers; (b) half-ripe fibers; (c) ripe or mature fibers. (After Beal.)

expand greatly. Balls<sup>1</sup> considers that the twisting of fibers is caused by the closing of simple pits in the wall of the fibers. These pits run through the cellulose of the wall obliquely, and as they close, because of the drying of the fiber, a twisting results.

**Form and Structure of a Mature Fiber.**—When magnified, a mature cotton fiber appears as a flattened, more or less twisted tube, the length ranging from 1,000 to 3,000 times the diameter. The form of a cotton fiber is sometimes compared to that of an empty fire hose; the comparison is apt except that the fiber is usually considerably more twisted (Fig. 38). The edges of the

The growth rings of the cotton fiber were rendered visible by treating the fibers for a short period with  $\text{CS}_2$  and  $\text{NaOH}$ , or with cuprammonium (Schweizer's reagent), which caused the cell wall to swell several times its original thickness. The layers may be seen with a microscope that magnifies 250 diameters, but much depends on the light used.

The fiber cells are cylindrical until about the time the boll begins to open, and they contain living protoplasm until this time. With the opening of the boll there is further loss of water, and the fibers become thoroughly dry. As water is lost, the cylindrical cells collapse, assuming a flattened, ribbon-like form, which shows a few to many twists (see Fig. 38). The twisting of the fibers as the boll opens causes the lock of seed cotton to

fiber appear somewhat thickened, but this is due to the folding of the wall. The diameter is slightly less toward the end that was attached to the seed, and the other end narrows to point in the last one-fourth of the fiber length. Throughout most of its length the fiber is very uniform in diameter.

A sample of lint cotton, on the basis of maturity or development shows various sorts of fibers. These are sometimes classed as (1) unripe, (2) half ripe, and (3) ripe. The unripe fibers have a very thin wall and lack twist (Fig. 38a). Such fibers are known technically as "dead cotton." They are of but little value. Being weak and brittle, they break up in the process of manufacture, increase the waste, and weaken the yarn. The ripe fibers are the normal type with thickened walls and good twist. In a good cotton, most of the fibers are of this type. The twists are sometimes in one direction and sometimes in the other. They occur at irregular distances. As a rule, the smaller the diameter of the fiber the larger the number of twists it has. Sea Island, a type with very fine fibers, has much twisted fibers. The twists cause the fibers to cling to each other and thus improve their spinning qualities. The half-ripe fibers are intermediate in character and value. If cotton bolls open prematurely because of drought, defoliation of plants by insects, or any other reason, the fibers are likely to be unripe or half ripe. The fibers produced by diseased plants or diseased bolls are faulty. Certain bolls on every plant fail to develop properly on account of their location, and consequently have poor fibers. This is especially true of the first bolls to set on a plant. Some fibers on every cotton seed fail to develop properly, and therefore produce faulty lint. Exposing seed cotton to sun and wind for a few hours after picking is thought by some to improve the staple. While it is doubtful if this helps the staple more than in making it thoroughly dry, it does make the cotton look better and become more fluffy and probably improves the grade to a limited extent. The notion is prevalent, also, that the character of cotton staple is improved by storing the seed cotton some weeks before ginning. It is said that the fibers become a rich creamy yellow by taking up oil from the seed and that their tensile strength is increased. In so far as the writer is aware, this contention has never been demonstrated by experimental tests. Miller,<sup>2</sup> an authority on cotton classing, thinks that such storage does have an influence.

Levine,<sup>3</sup> in his study of the structure of cotton fibers, identified five different parts in a mature fiber:

1. The integument, or outer layer. This is commonly known as the cuticle or waxy layer. Levine found it to contain a mixture of cutinous, pectinous, gummy, fatty, and other unidentified bodies.
2. An outer cellulose layer, which is largely the original cell wall.
3. The layer of secondary deposits. This is nearly pure cellulose. Balls,<sup>1</sup> as was mentioned above, observed numerous concentric layers in this portion of the fiber wall, and also oblique simple pits.
4. The walls of the lumen, a spiral structure surrounding the central cavity of the fiber and more dense than any other part of the fiber.
5. The substance in the lumen, structureless and of a nitrogenous nature.

Evans<sup>4</sup> estimates that 85 per cent of the fiber is cellulose and that 2 per cent of its weight is due to the waxy deposit. The presence of the latter makes cotton somewhat impervious to water. It is removed from absorbent cotton and from cotton that is to be dyed.

**Fuzz.**—After the lint fibers are removed from cotton seeds, there remains on the seed, in most varieties, a velvety covering of short cotton hairs known as fuzz. The fuzz hairs, as was mentioned above, are produced by the outgrowth of epidermal cells in a way very similar to the growth of lint hairs. They are much shorter than lint hairs, ranging from  $\frac{1}{8}$  to  $\frac{1}{2}$  inch or more in length. The longer hairs found in linters are mostly regular lint hairs that the gin failed to remove at the first ginning. The fuzz fibers, as a rule, have a greater diameter than the lint hairs, but as the cell wall is thin, they resemble immature or undeveloped fibers. They are light and weak in body.

**Effect of the Environment of Cotton Plants on Staple.**—For cotton plants to produce fiber of normal length and strength, they require rather favorable environmental conditions continuously. If the conditions are not favorable, the lint will not grow to full length. Good culture makes conditions better, especially by regulating the supply of moisture. Cook<sup>5</sup> expresses the belief that the Delta regions of Mississippi and Louisiana are well adapted to the growth of staple cottons because there is a more

uniform supply of moisture than in many other regions. Balls<sup>6</sup> found, by measuring the lint length of the cotton in certain dated bolls of Egyptian cotton, that there was a definite relation between periods of irrigation and lint length. The bolls which had lint lengthening at the time the water supply was most abundant made the longest lint. A difference of nearly 2.5 millimeters was noted. The effect of the irrigation showed on the third or fourth day after watering and continued until about the tenth day. Kearney<sup>7</sup> reports that complaints are sometimes made by the consumers of Pima cotton that there are bales of mixed staple. This is a very uniform variety of cotton when grown under uniform conditions, but it was found that in fields where there were sandy, alkali, or more or less barren spots the lint produced by plants grown on those spots was decidedly inferior. This explained the finding of mixed staple in certain bales, since seed cotton from all parts of the field was picked and put together.

In 1923, the writer obtained from the Staple Cotton Cooperative Association Classers of Greenwood, Miss., the classing data in regard to staple cotton grown on four large plantations in the Mississippi Delta that year. Seventy-seven per cent of the bales were classed as full  $1\frac{1}{8}$  inches. This was a rainy season, rainfall for the year being 81 inches at the nearest weather observation station. In 1924, which was an abnormally dry year with a rainfall of about 41 inches, the summer being exceptionally dry, similar data were collected. The variety of cotton, the plantations, and classers were the same the two years. In 1924, 70 per cent of the bales were classed as straight  $1\frac{1}{8}$  inches. There was a difference of  $1\frac{1}{32}$  inch, due very probably to the difference in water supply. The cotton was better cultivated in 1924 than in 1923.

**Length of Cotton Fibers.**—The length of cotton fibers is an hereditary character. It is influenced to a limited extent, as has been seen, however, by environmental conditions. The principal species and varieties of cotton vary much in length of staple. Table III from Cook<sup>8</sup> gives the staple length, color, relative yarn counts for which they are commonly used, and the relative values of the principal types of cotton. Pictures of seeds of the foregoing types of cotton with combed lint attached are shown in Fig. 14.

TABLE III.—A SELECTED LIST OF COTTONS, SHOWING CHARACTER AND RELATIVE PRICES

Country	Variety	Aver- age length, inches	Rela- tive value	Counts up to	Color	Remarks
America....	Sea Island (South Carolina).....	2	230	300	Cream	Silky and regular
	Sea Island (Georgia and Florida).....	1 <sup>5</sup> / <sub>8</sub>	215	200	Cream	Silky and regular
Egypt.....	Sakellaridis.....	1 <sup>1</sup> / <sub>2</sub>	173	150	D a r k cream	Silky and soft
	Nubari.....	1 <sup>3</sup> / <sub>8</sub>	160	100	Light brown	Silky and weak
America....	Long-staple Upland.....	1 <sup>1</sup> / <sub>4</sub>	160	60	White	Soft and strong
	Short-staple Upland.....	1	100	40	White	Soft and strong
India.....	Tinnivelly.....	7 <sub>8</sub>	95	30	White	Best of Indians
	Surat, Broach, etc.....	7 <sub>8</sub>	91	30	Light brown	Harsh, strong
China.....	Sind.....	5 <sub>8</sub>	71	10	D u l l white	Poor
		3 <sub>4</sub>	88	20	D u l l white	Rather harsh

The length of fibers within a single lot of cotton varies considerably, being greater for the cottons with extra staple length and less for well-bred varieties with which an effort has been made to make the staple length uniform. On seeds from strains that have not been selected for lint uniformity, very frequently the fibers on the pointed end of the seed are considerably shorter than those on the larger end, the difference being  $1\frac{1}{4}$  inch, or more in some cases. The range is often greater than the difference between varieties, average lengths being considered. There is frequently a difference of  $1\frac{1}{16}$  inch or more in the staple length of different bolls. This probably depends to some extent on the weather conditions prevailing when the particular bolls were developing. In some observations made by the writer, the first formed bolls, which were low on the plant, had shorter staple than the average. The ones above these were longer; then there was shorter lint toward the top of the plant and toward the outer end of the branches.

There is also, of course, considerable variation in staple length between different plants of a strain—the better bred a strain the less the variation.

The diameter of cotton fibers ranges from about 0.000640 inch (16.3 $\mu$ ) for Sea Island to 0.000844 inch (21.5 $\mu$ ) for the coarsest

Indian varieties. Upland varieties are intermediate, being about 0.000763 inch ( $19.4\mu$ ) in diameter. As a rule, the longer a fiber is the smaller its diameter.

**Strength of Fibers.**—Cotton graders estimate the strength of cotton fibers by breaking small tufts clasped between thumb and forefinger of each hand. That their judgment is not altogether reliable is shown by the fact that the results from spinning tests may not agree with their classing, and that figures obtained by

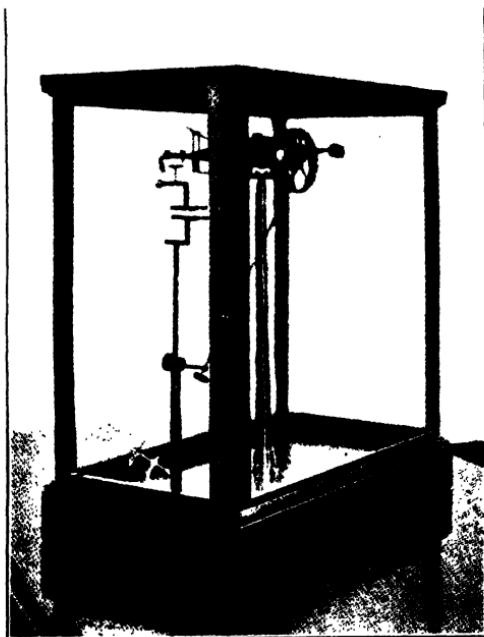


FIG. 39.—Fiber tester with a capacity of 0.1 to 50 grams, used in determining the strength of cotton fibers. (After Dewey.)

breaking individual fibers with a machine do not tally with their conclusions in many instances. Balls<sup>5</sup> from actual tests made concludes that graders' "strength" and "breaking strain" are utterly disconnected and have nothing to do with each other. He considers that what the grader determines is nearer "impact" resistance than actual strain that the fibers can withstand.

The actual breaking strain of individual fibers may be determined accurately by clasping the ends of a single fiber between the jaws of a fiber-testing machine (see Fig. 39) and applying

the strain gradually. Table IV from Dewey<sup>9</sup> gives the breaking strain in grams of fibers of several most important types of American cotton. The figures for the highest and the lowest are averages of twenty fibers.

TABLE IV.—TENSILE STRENGTH OF COTTON FIBERS

Variety of cotton	Breaking strain, grams		
	Highest	Lowest	Average
<b>American Upland:</b>			
Big Boll Stormproof group.....	9.0	5.2	6.67
Big Boll group.....	11.6	4.6	6.60
Cluster group.....	7.7	5.1	6.00
Semicluster group.....	7.1	4.7	5.86
Peterkin group.....	6.0	5.0	5.70
Early group.....	6.9	5.2	5.63
Long-staple group.....	5.6	3.5	4.72
Sea Island.....	7.6	4.7	6.14
Egyptian from California and Arizona.....	8.0	5.6	6.65

The actual strength shown by fibers varies considerably, depending on humidity of the atmosphere, the part of the fiber exposed between the jaws of the machine, the part of the seed from which the fiber came (the fibers are weaker toward the pointed end of the seed), and the boll or plant from which the fiber came.

The strength of a fiber depends principally on the thickness of its cell wall. The strength is not necessarily proportional to the diameter since some fibers with thin walls may be large in diameter but weak in strength. The strength of mature, well-developed fibers is, in general, in proportion to their diameter.

There is much variation in the strength of cotton fibers on account of changes in the environmental conditions under which the plants were grown. The different environmental factors mentioned on a preceding page as affecting length also affect the strength of fibers. The effect in this instance is even more striking than in the former.

**Relation of Yarn Strength and Fiber Strength.**—The strength of yarns spun from cotton fibers is not determined altogether by the strength of the individual fibers contained. When a yarn

breaks, not many of the fibers are broken; they are simply pulled apart. Much then depends on the way the fibers twist about one another and cling together. Long fibers with numerous twists or convolutions make the strongest yarns, everything else being the same.

**Fineness.**—The lint of certain kinds of cotton, such as Sea Island, has a soft or silky feel and is considered fine lint. The lint of other kinds, such as the Indian wool cotton (*G. arboreum*, var. *assamica*), has a very harsh feel and is considered coarse. A microscopical examination of the fibers of the two types of cotton shows that the Sea Island cotton has fibers of somewhat smaller diameter than the other, but the chief difference is in the much thicker cell wall of the Indian type, which gives it the character of coarseness.

**Uniformity of Fibers and Spinning Qualities.**—The machines in cotton mills are set for certain fiber lengths. If there are many fibers in the lint cotton which are considerably shorter than those for which machines are set, a considerable amount will go into the waste. The ideal fibers for spinning purposes are those that are of uniform length, diameter, cell-wall thickness, and twist. Such fibers may be spun economically; if their diameter and twist or convolutions are uniform, they will fit together closely, thus making a strong thread; if their cell walls are uniform, they will take dyes more uniformly.

Since many varying factors have a bearing on lint uniformity, it will never be possible to secure lint with a near approach to uniform fibers; they do not and cannot grow that way. By growing pure strains of cotton that have been especially selected for uniformity of staple, considerable improvement may be made over the present supply.

**Color and Luster of Lint Cotton.**—The lint of the wild cottons is, as a rule, a brownish or "khaki" color. Reversions or sports with lint of this color are occasionally found in nearly all varieties of cotton. Less frequently plants are found which have a green lint similar in hue to that of the green fuzz on some seed. This lint is of a clear-green color when the boll first opens, but on exposure to light it fades to a tawny brown.

The color of the standard cultivated races of cotton ranges from pure white, as found in American Uplands; cream, illustrated by Sea Island; dark cream, like Egyptian Nubari; to brown, as found in Egyptian Ashmouni.

Cotton that is exposed to the weather for a long time before it is picked tends to take on a dull-white or bluish color. This is objectionable, because such cotton does not bleach or dye well. Some cotton is spotted, yellow-stained, or tinged, as a result of insect or frost injury.

The luster of lint is commonly thought to be due to variations in the reflection of light from different parts of the cuticularized walls of the exposed fibers. Balls<sup>6</sup> considers that luster is more than simply reflection of light. Luster is temporary and easily lost; yet the cuticle which is supposed to form the reflecting surface is very resistant. He believes that the fibers which are translucent refract a certain amount of light, and there is reflection also from concave surfaces within the fiber.

**Lint Percentage.**—The ginning outturn or lint percentage is determined by at least three factors: the number of fibers per unit area of seed surface, the size of the fibers, and the weight of the seed. The variation of different varieties with respect to the number of fibers per unit area of seed surface has not been investigated thoroughly, but it is known that some of the short-staple varieties with high lint percentage do have many more fibers per seed than do the varieties with longer staple and lower percentage. It is probable that, in general, the number of fibers varies directly with the lint percentage. The size of the individual fibers is a factor of relatively little importance in its effect on lint percentage. The long fibers have a small diameter, and the short fibers are relatively thick; so these characters tend to balance each other. The size or weight of the seed is also another important factor in determining lint percentage. Varieties with the highest lint percentage have small seeds, whereas some varieties with low percentage have large seeds.

Growers are partial to a cotton that turns out well at the gin, and within certain limits buyers prefer staple from cotton that turns out well. While it may be possible to reduce the vitality of seeds by selecting small-seeded strains for a series of years in effort to raise the lint percentage, it has been the writer's experience that, everything else being equal, the small-seeded strains are preferable on account of their quicker germination, greater ease in getting a stand of plants, higher oil content, and better lint percentage. Rowden, a variety with very large seeds, has usually given poor stands.

Cotton grown on rich land or on land that has been given a liberal application of nitrate of soda has a lower lint percentage than cotton grown on less productive soils. The difference in this case is due to the richer lands producing heavier, plumper seeds. The better lands produce longer fibers and probably slightly more lint per seed, but this is more than overbalanced by the increase in the weight of seeds. In tests conducted by the writer, of eleven different varieties on four different types of soil, the plantings on the poorer soils gave higher lint percentages consistently. In 1923, the average difference was 1.7 per cent.

TABLE V.—RANK OF VARIETIES IN LINT FREQUENCY, LINT INDEX, LINT PERCENTAGE, AND LENGTH OF LINT (After Hodson)

Variety	Rank in lint frequency	Rank in lint index	Rank in lint per- centage	Rank in length of lint
Boykin.....	1	2	2	25
Cook.....	2	11	9	24
Triumph.....	3	1	3	16
Roundnose.....	4	5	6	18
Cleveland.....	5	12	7	19
Christopher.....	6	8	12	15
Texas Bur.....	7	6	5	11
Culpepper.....	8	9	8	12
Lone Star.....	9	3	4	8
Covington-Toole.....	10	13	10	22
Spruill.....	11	7	16	9
Acala No. 5.....	12	4	1	6
Half and Half.....	13	16	13	20
King.....	14	15	14	13
Rublee.....	15	14	15	17
Rowden.....	16	10	11	7
No Chop.....	17	18	18	21
Simpkins.....	18	21	17	23
Trice.....	19	17	19	14
Dixie-Improved.....	20	23	20	10
Foster.....	21	20	21	5
Express.....	22	24	24	4
Columbia.....	23	19	22	2
Webber-49.....	24	22	23	3
Dix-Afifi.....	25	25	25	1

Considering that there is danger of causing the deterioration of varieties if selections are made on the basis of lint percentage,

Cook<sup>11</sup> suggests that the weight of lint produced by a hundred seeds, a lint index, be used instead. But it is doubtful if this is of any considerable value to cotton breeders, since it does not give any measure of the yield of lint per acre, which is really the principal feature.

Hodson<sup>12</sup> suggested the term "lint frequency," which he defined as "the weight in grams of the fiber of uniform length produced per square centimeter of seed surface." "Lint frequency," however, does not differ greatly from "lint index"; only in the former more stress is placed on seed surface area. Table 1 from Hodson,<sup>12</sup> shows the relative rank of certain varieties in lint frequency, lint index, lint percentage, and lint length. A study of this table gives some idea of the relation of these different characters.

**Chemical Composition of Lint Cotton.**—The chemical composition of cotton fibers is given in Table XXII and in other tables in Chap. X.

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## CHAPTER VIII

### VARIATION, HEREDITY, AND CORRELATION OF CHARACTERS IN COTTON PLANTS

A discussion of heredity and related subjects in a book of this type finds its justification in the following facts: The amount of cotton produced in a field or in any locality depends on the yielding power of the plants grown. This yielding power is influenced greatly by certain inherent traits that the plants possess. Good-yielding strains may be maintained by cotton breeders who choose plants that have these desired traits and propagate from them. They are helped greatly in making their choices by a knowledge of the laws of variation. They should be able to distinguish between mere fluctuations caused by difference in environmental conditions and really significant variations. They need to know what characters are hereditary and what laws govern their inheritance.

**Variations.**—No two cotton plants are exactly alike. The differences that the individuals of a variety or species exhibit are known as "variations." Variations are of different types, but they may be grouped in two general classes, continuous or non-heritable and discontinuous or heritable. The continuous variations are mere fluctuations in plant characters caused by differences in the environmental conditions under which the plants grow. The discontinuous variations, on the other hand, are not due to external influences, but to some change in the genetic constitution of the plants.

Wild species of cotton, like the wild species of most other plants, are relatively fixed and stable. The variations they show are almost all of the continuous type. Cultivated varieties of cotton are more variable, the non-heritable variations fluctuating through a wider range and the heritable occurring more frequently. This is partly due to the fact that cultivated plants have better growing conditions. They are not crowded by grass, weeds, and other plants like the wild plants. They are plowed

and hoed, which makes moisture and nutrient elements more available and more plentiful. Each plant has a better chance to show its individuality.

The heritable variations fall into two classes: mutations, and new combinations of characters resulting from segregation in strains of hybrid ancestry. Mutations are marked variations in the characters of individuals which are caused by sudden changes in the hereditary constitution of the parent organism, or by chromosome aberrations. Mutations will be discussed further in a later paragraph.

Heritable variations due to the segregation and recombination of factors are common in cotton. Varieties and even species having markedly different characters are frequently allowed to hybridize. The cross brings together various factors that belong to the two parents. These factors enter into different combinations, some of which produce characters such as are found in one parent, some like ones found in the other parent, while there may be still other characters that are different from anything found in either parent. The number of apparently independent characters of cotton plants is large—probably in the hundreds—and the factors responsible for these characters are even greater in number. With the large number of factors almost innumerable factor combinations are possible. This accounts for the large number of various character combinations found in a field of cotton. None of the commercial varieties of cotton are genetically pure, in the sense of being pure lines. All are of more or less hybrid constitution and it may be expected that segregation will occur frequently and new forms will appear often. This may be a help to the cotton breeder in that desirable new combinations or plant types may be found easily, but it is also a disadvantage in that the desirable new strains may not be very permanent.

**Mendel's Laws.**—The first investigator to formulate definite laws of heredity was Mendel, whose work, published in 1866, was brought to the attention of the scientific world in 1900. He discovered that genetic factors tend to *segregate* in the offspring of hybrid plants, and that the segregation which occurs between the members of one pair of factors is *independent* of that in others. These two principles, with certain modifications and amplifications which have since been made, particularly a recognition of the occurrence of linkage and of the operation of multiple factors,

have made it possible to understand and explain many of the complexities of inheritance and to put the problems of plant breeding on a scientific basis. Most of the important types of Mendelian inheritance have been found in cotton.

**Heredity.**—It is a matter of common observation that a plant inherits its characteristics from its parents or resembles them in most respects. The tendency is for the parent forms to be reproduced true to type, or very nearly so, and the stability of our agricultural varieties depends on this fact.

**Mendelian Inheritance in Cotton.**—The application of Mendel's law to inheritance in cotton has been studied by Kearney,<sup>1</sup> Balls,<sup>3</sup> Fletcher,<sup>4</sup> Tyson,<sup>5</sup> Harland,<sup>6</sup> Leake,<sup>7</sup> Leake and Prasad,<sup>8</sup> McLendon,<sup>9</sup> and others. These investigators secured similar results in general. If the character was controlled by a single factor, as are most of the color characters, simple Mendelian ratios were obtained. But with the majority of the traits considered, simple ratios were not found. Kearney<sup>1</sup> plotted frequency distributions for each of the thirty-nine characters he studied in the second generation of a hybrid between Holdon, an Upland variety, and Pima, an Egyptian variety. But three of his graphs are bimodal or multimodal, hence only the three characters, petal spot, anther color, and midlock furrow of the boll, showed direct evidence of segregation in Mendelian proportions.

**Leaf Color.**—Simple Mendelian ratios were obtained by Leake,<sup>7</sup> McLendon,<sup>9</sup> and by the author in the study of the inheritance of leaf-blade color where a red-leaf variety was crossed with one with green leaves. The  $F_1$  plants had reddish-colored leaves but the color was not so dense as in the red-leaf parent.

**Petal Color.**—Results obtained from the study of the inheritance of petal color in cotton hybrids have varied considerably. Kearney<sup>1</sup> found his  $F_1$  plants to have petal color intermediate between the light-colored petals of the Holdon parent and the yellowish petals of the Pima parent. His  $F_2$  plants gave a unimodal frequency curve extending from one parental extreme to the other, with the majority of the individuals on the side next to the lighter-colored flowers.

Tyson<sup>5</sup> reported complete dominance of yellow in the  $F_1$  generation of a cross of white- and yellow-flowered Indian cottons. The  $F_2$  generation showed 156 individuals classed as pale and 411 classed as white.

Balls<sup>3</sup> states that in crosses of Upland and Egyptian cottons the  $F_1$  plants always have intermediate petal color. Certain crosses gave a near approach to the 1:2:1 ratio in the  $F_2$  generation, but further study of segregation in later generations indicated a more complex inheritance. From all the evidence he secured Balls decided that the petal color of crosses of Upland and Egyptian cottons is controlled by not less than three pairs of factors.

*Petal Spot.*—Balls<sup>3</sup> reports that a cross of Egyptian cotton, which has a bright red or "full spot" on the claw of the petal, with Upland, which has no spot, gives an intermediate  $F_1$ . In the  $F_1$  the spot is smaller and has a more vague outline than in the Egyptian parent. Some of Balls' crosses gave an approximation of the 1:2:1 ratio in the  $F_2$ , as, for instance, twenty-three full spot, forty-two intermediate, and thirty-one spotless; in other crosses the numbers were much different, as, for instance, 2:40:115. Balls says:

The only decision at which we can arrive with certainty is that the presence or absence of the petal spot in these Egypto-American crosses is not determined by a single pair of allelomorphs.

Leake and Prasad<sup>8</sup> reported complete dominance of petal-spot color in the  $F_1$  in a cross of Chinese cotton without a petal spot and an Indian cotton with one.

McLendon<sup>9</sup> considered the petal spot to be intermediate in the  $F_1$  of a cross between Sea Island and Upland cottons; most of his  $F_2$  progenies showed a ratio approaching 1:2:1.

Kearney<sup>1</sup> found the petal spot in the  $F_1$  of the Holdon  $\times$  Pima hybrids he studied to be dominant but reduced in size. The  $F_2$  generation gave a very close approach to a 3:1 ratio.

*Anther Color.*—Hybrids of Egyptian and Upland varieties made by Balls<sup>3</sup> showed the  $F_1$  anther color to be intermediate, and a true 1:2:1 ratio was obtained in the  $F_2$  generation. No exceptions were noted in later generations.

Kearney<sup>1</sup> secured only partial dominance for the yellow color in the  $F_1$  of the Holdon  $\times$  Pima cross he made. The  $F_2$  gave some evidence of bimodal distribution.

*Boll-lock Number.*—The average number of locks to the boll in the  $F_1$  generation in the Holdon  $\times$  Pima hybrid studied by Kearney<sup>1</sup> was exactly intermediate between the averages of the parents. The  $F_2$  generation gave a unimodal distribution, which indicated that several factors were active in determining the boll-

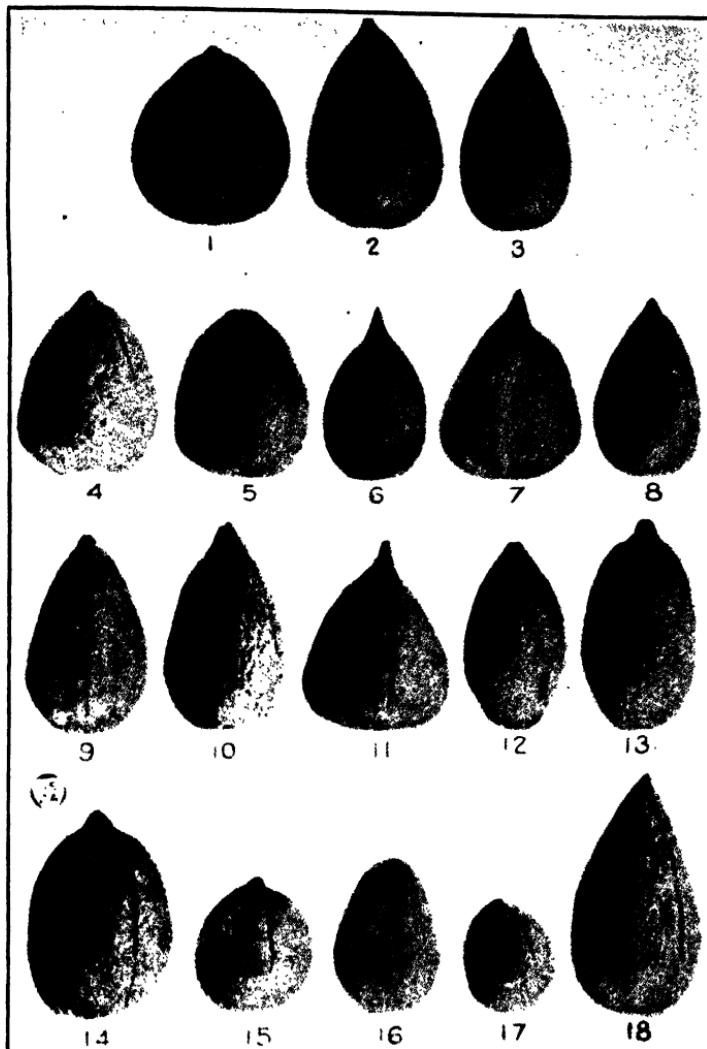


FIG. 40.—Bolls of the parental and hybrid cotton plants. (1) The Holdon parent, showing the relatively large maximum and apical diameters, almost complete absence of a beak, short midlock furrows, light color, and smooth surface, the oil glands being very inconspicuous. (2) The first-generation hybrid, intermediate in shape, relative diameter and character of the surface, but resembling the Pima parent in having a well-developed beak and no midlock furrow. (3) The Pima parent, showing the relatively small maximum and apical diameters, conspicuous beak, absence of a midlock furrow, dark color, and pitted surface. (4) to (18) Second-generation hybrid individuals, showing variations as follows: (4) The most Uplandlike; (8) the most Pimalike; (4) and (5) very light and very dark colored; (5) and (6) beakless and strongly beaked, (9) and (10) very smooth and very rough surface; (11) to (16) extreme variations in shape; (17) and (18) very small and very large; (7) and (9) presence of midlock furrow in different degrees; (16) and (18) termination of the lock furrows at considerable distances from the base of the boll. (After Kearney.)

lock number. Balls<sup>3</sup> secured similar results when studying this character.

*Boll Shape*.—Boll shape is not due to a single factor, but is determined by several factors. Kearney,<sup>1</sup> using ratio of diameter to length as a character index, found the mean of  $F_1$  to be intermediate between the means of the parents (Fig. 40), while the  $F_2$  frequency distribution curve did not show clear segregation. This probably indicated a series of multiple factors. Balls<sup>3</sup> secured similar results in his studies of this character.

*Fiber Length*.—McLendon<sup>9</sup> in crosses between Sea Island and Cook, and between Sea Island and Hastings Big Boll (Cook and Hastings being Upland short-staple varieties), secured intermediate fiber length in the first generation. The second generation segregated into about three-fourths long to one-fourth short.

Balls,<sup>10</sup> with crosses between Egyptian and Upland varieties, obtained results similar to McLendon's.<sup>9</sup> In a cross of Egyptian Afifi with a short-staple Upland variety,  $F_1$  plants were obtained which had a staple length greater than the Afifi parent. The writer secured a similar intensification in  $F_1$  hybrids of a cross between Trice and Triumph, both Upland short-staple varieties. The hybrid had staple  $\frac{1}{8}$  inch longer than either parent.

In the Holdon  $\times$  Pima cross, Kearney<sup>1</sup> obtained  $F_1$  plants with a mean fiber length nearly equal to the mean fiber length of the long-fibered Pima parent. His  $F_2$  plants gave a unimodal curve which was nearly symmetrical.

*Fiber Color*.—First-generation hybrids of a cross made by the writer between Cleveland, a short-staple variety with white lint, and the so-called "Nankeen" cotton, a short-staple variety with brown lint, had uniform brownish, cream-colored lint, intermediate between the two parents in color. Selfed seed from the  $F_1$  plants gave an  $F_2$  generation which segregated in almost an exact 1:2:1 ratio.

Balls<sup>3</sup> crossed brown-linted Egyptian varieties with Uplands with white lint. The first crosses showed an intermediate cream-colored  $F_1$  and an  $F_2$  with twelve brown, twenty-one creamy, and eleven white. The browns and whites bred true up to the fifth generation, while the creamy-colored ones broke up. Later crosses made by Balls gave more complicated results.

*Seed Fuzziness*.—McLendon, from crosses of smooth- and fuzzy-seeded varieties, reports fuzziness dominant to smoothness in the  $F_1$  generation. In the  $F_2$  generation the ratios ranged

from 1:1 to 18.6:1 for different crosses. This indicates that segregation is complex.

Kearney<sup>1</sup> found the fuzziness of the Holdon parent to be dominant over the smoothness of the Pima parent in the  $F_1$  plants. The  $F_2$  generation gave no evidence of definite segregation (Fig. 41).

Winters, in some unpublished work on the study of fuzz inheritance, finds indications of a single factor difference, with the fuzz-

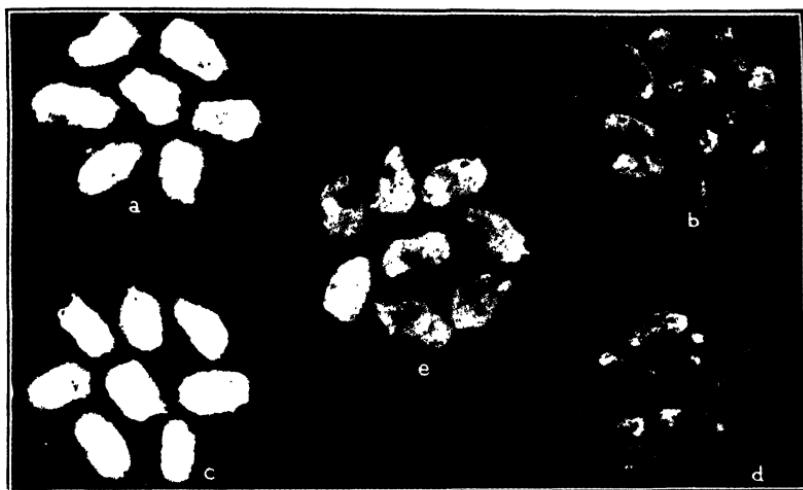


FIG. 41.—Seeds, after removal of the fiber, of the parental and hybrid cotton plants. (a) The Holdon parent, having the seed completely covered with long white fuzz; (b) the Pima parent, having the seeds partly covered with short greenish or brownish fuzz; (c) and (d) the fuzziest seeded and the smoothest seeded second-generation hybrid plants; (e) the first generation hybrid, having the seed completely covered with long green or white fuzz. (After Kearney.)

less character dominant. He says in a personal letter, "There exists a fuzz pattern character which may be confused with the fuzzless character. This behaves quite differently and may account for the varying results."

Balls,<sup>3</sup> in discussing the inheritance of seed fuzziness, says:

In crosses of any Egyptian with American Upland, we meet with complications. The entire fuzz is dominant, and the  $F_2$  has given such 15:1 ratios of "entire:slight," as 97:6, 180:11, etc.

**Inheritance of Other Characters.**—The inheritance of a number of other characters of the cotton plant has been studied by Kearney,<sup>1</sup> Balls,<sup>3,10</sup> McLendon,<sup>9</sup> and by others. These additional

characters include leaf shape, color of fuzz on seeds, prevalence of glands on different parts of plants, pitting of boll surface, pistil length, stamen length, calyx dentation, etc. (Fig. 42). The results obtained did not differ materially from the ones outlined above, except that perhaps, in general, the segregation was not so definite. There are many other characters that have not been carefully studied.

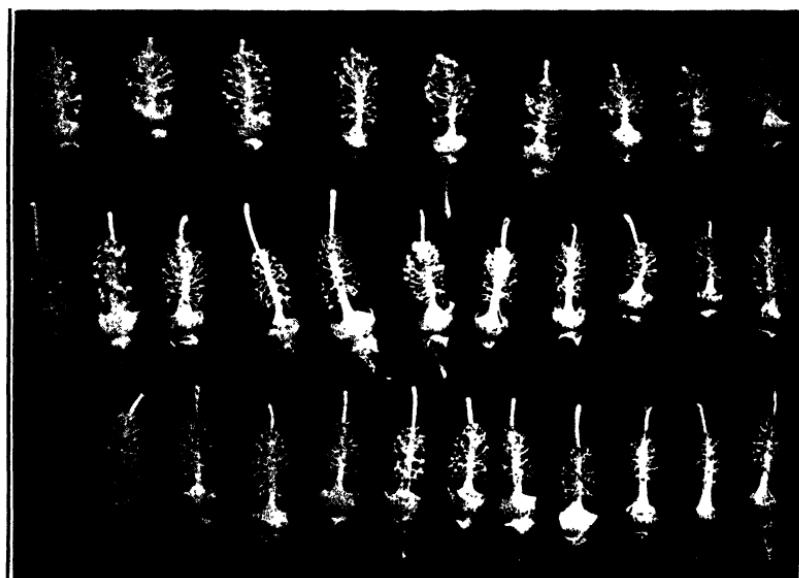


FIG. 42.—Cotton flowers showing stamens and pistil. The first flower in the upper left hand corner of the figure is from Upland cotton; the last one in the lower right hand corner is from Sea Island; the rest are from  $F_2$  hybrids between Upland and Sea Island.

**Inheritance of Quantitative Characters.**—The inheritance of quantitative characters, such as size, weight, height, etc., is of much importance, economically considered, for values are largely determined by the quantities produced. The inheritance of quantitative traits is difficult to study because, as a rule, each character is under the control of several factors, and because the characters are subject to non-heritable fluctuations caused by differences in environmental conditions. These fluctuations may be wide and such as to render the placing of individuals in proper classes difficult. It was thought at first that quantitative characters did not follow Mendel's law in their inheritance, since for most characters there seemed to be a continuous graduation in

the  $F_2$  hybrids from one parental form to that of the other. After it was discovered that two or more factors are necessary, in some cases, for the production of certain simple characters such as color, it was but a step to use this information in working out the inheritance of quantitative traits.

Comparatively little work has been done on an analysis of quantitative characters in cotton. Kearney,<sup>1</sup> however, shows clearly that they tend to resemble, in their inheritance, similar traits in other plants, the  $F_1$  of a cross between two pure parents tending to be more or less intermediate between them and no more variable than either, but the  $F_2$  showing a greatly increased variability, thus indicating the occurrence of segregation in a group of multiple factors. In a cross between the Holdon and Pima, for example, Kearney finds that the mean fiber length of the former is 2.1 units, with a standard deviation of 0.5; of the latter, 7.4 units, with a standard deviation of 0.6; of the hybrid offspring ( $F_1$ ), 6.6, with a standard deviation of 0.7; and of the second-hybrid generation ( $F_2$ ), 5.0, with a standard deviation of 1.5.

**Linkage of Characters.**—It is the common belief among students of heredity that the physical basis of each hereditary factor is to be found in the chromosomes of the cell nucleus. The chromosomes are fairly permanent structures, each species or variety of plants having a regular number in its cells. Since the number of hereditary factors belonging to an individual, either plant or animal, is usually several times the number of its chromosomes, it seems evident that certain factors must occur together in the same chromosome and be transmitted together, or *linked*. That this is true has been well demonstrated by Morgan and his associates in their breeding experiments and cytological studies with the fruit fly, *Drosophila*. This insect has only four pairs of chromosomes but more than 300 factors have been identified, most of which have been proved to be linked.

In cotton, according to the studies of Denham and Beal (see Chap. VIII), there are twenty-six chromosomes. Since the genetic factors in cotton are doubtless far more numerous than this, there must be many cases of linkage between factors. But little attention has been given this subject by students of heredity in cotton. Thadani<sup>17</sup> in recent studies has observed what he considered well-defined linkage between certain factors. A naked-seeded (*A*), sparse-linted (*b*) variety was crossed with a

fuzzy-seeded (*a*), abundant-linted (*B*) variety. A naked-seeded, abundant-linted type was obtained in the *F*<sub>1</sub> generation. In the *F*<sub>2</sub> generation the segregation was as follows: 103 *AB*: 54 *Ab*: 53*aB*: 0*ab*, thus indicating that there is linkage between these two pairs of factors.

**Mutations in Cotton.**—As was mentioned on a previous page, mutations are heritable variations which are not the result of segregation and recombination of genetic factors. They are marked by the sudden appearance of new forms among the progeny of pure races. The mutant may differ from other individuals of the progeny in respect to but one trait, but often it has several rather striking character differences.

The cause of mutations is not well known. They may be due to alteration in the genetic factors of body or germ cells; or to deviations in the number of chromosomes. The first class is probably the more important.

In common with most other cultivated plants, mutations occur in cotton, but it is a question as to how frequent they are. Because there is hybridism in the ancestry of most cotton varieties, it seems reasonable to believe that many of the new forms or types that appear in cotton fields are the result of segregation and new combinations of factors from parents that were hybridized in previous generations. Whether the new forms arise from mutations or from hybrid segregation is very difficult to determine, but it appears probable that mutations may be expected in cotton as frequently as in other cultivated crops.

A number of new forms or types have appeared and behaved in such a way that they fit the definition of mutants. Kearney<sup>12</sup> offers the following argument in favor of the theory that certain new strains or varieties of cotton have originated as mutants:

(1) The derivation of each from a single plant discovered in a field of very different cotton; (2) the distinctness of their botanical characters, especially in the recently developed Nubari and Sakellaridis (Egyptian varieties); and (3) their tendency to remain uniform.

In the cotton-breeding fields of the Mississippi Experiment Station several distinct and unique plants have been found, from some of which new strains or varieties have been developed. One appeared in a field of Lone Star, the selected plant being designated as Lone Star-132. This new plant differed from the plants about it in habit of growth, being rather tall and narrow;

in shape of leaves; in size and shape of boll; in lint length, being about  $\frac{1}{8}$  inch longer than that the other plants; and in lint percentage. The other plants had a rather high lint percentage, running about 35, whereas the new variety had a low lint percentage, running about 28. Progenies grown from this plant were unusually uniform, considering the fact that the original plant and progenies were subject to open pollination. The new variety developed from this plant was uniform as long as it was grown (about 4 or 5 years) and yielded well, but it was discarded on account of some undesirable qualities. The original appears to have been a mutant. It resembled no known variety.

Another remarkable plant appeared in a field of Express cotton, from which was developed the strain Express-432. This plant also differed from the other plants of the field by marked characteristics and gave rise to a well-defined, uniform new strain which is grown commercially. It has been grown 10 years and is still essentially uniform. It possessed certain characters widely different from the parent variety and different from others known. Numerous selections made from the 432 strain have not proved to be an improvement over the original. Kearney<sup>12</sup> reported similar experience with selections made from Pima cotton, which is thought to have originated as a mutant.

A large number of the present varieties of Upland cotton have been developed from certain unusual individual plants. Lone Star, Triumph, Webber, and Express may be mentioned as examples.

Each of the more important recent Egyptian varieties is regarded by Kearney<sup>12</sup> as arising from a mutant—"from an individual plant that showed an abrupt and definite change in the characters expressed." Four distinct mutants have appeared in the plots or fields of Egyptian cotton grown in Arizona. Two of these gave rise to Yuma and Pima, commercial varieties of considerable importance.

**Correlation of Characters in Cotton.**—There are several characters of cotton plants that are generally considered to be positively correlated or connected in some way in their inheritance. Among the most common ones are:

1. Large bolls and large seed.
2. Long staple and small bolls (some of the long-staple varieties of recent origin, like Webber, for instance, have apparently

large bolls, but the seed cotton within does not weigh in proportion to the boll length and diameter).

3. High lint percentage and short lint.

4. Large seeds and low lint percentage.

5. Small seeds and high oil content of seeds.

6. Length of stem axis and branches, and date of maturity.

On the other hand, there are several characters that appear to be antagonistic, or negatively correlated. These are listed by Duggar<sup>14</sup> as follows:

1. Extreme earliness is opposed to large bolls.

2. Extreme earliness is usually not associated with the highest yields of lint, except when the fruiting season is shortened by early frost or by the presence of the boll weevil.

3. Great length of lint excludes the probability of a high percentage of lint.

While statements have often been made concerning the correlation or antagonistic relation of several of the above-mentioned characters, there has been a scarcity of reliable data on the subject. Characters were said to be correlated, but no statistical data were given to prove it. Within the last few years valuable data on the subject have been published by Kearney,<sup>1</sup> Dunlavy,<sup>2</sup> and Hodson.<sup>15</sup> Their papers give statistical data on the correlation of a large number of the characters of cotton plants, but only a limited amount of this information is of direct agricultural value.

Plant breeders must depend largely on the physical characters exhibited by plants as a guide in making selections or in isolating new strains. But it is often impossible to tell by observation alone what character combinations will be best or will result in the most productive progenies. A certain amount of aid may be gained from correlation statistics, if available. On this subject Babcock and Clausen<sup>16</sup> say:

Biometricians consider the correlation coefficient the most powerful tool the agricultural investigator can have, since it is a most excellent measure and is applicable to an immense range of variables. Remembering that this constant is an index of the mutual relation that exists between the variations of any two characters, we realize that, if it is high, it indicates that they are in some way closely related, and, if it amounts to unity, it shows that one is the cause of the other or else both are the result of the same causes.

From Hodson's<sup>15</sup> work it seems that the degree of correlation between certain characters of the cotton plant varies considerably with the variety used and with climatic or other conditions prevailing during different years.

Table VI, after Dunlavy,<sup>2</sup> gives the correlation existing between a number of different characters in a Texas cotton. The variety is not named, but it is taken to be one of the Texas big-boll medium-staple cottons, since they are the principal cottons grown in that state. The data were taken from choice plants selected for progeny row work. The number used ranged from 70 to 167. The fact that only select plants were used limits the application to such plants.

TABLE VI.—CORRELATION BETWEEN CHARACTERS IN 167 INDIVIDUAL COTTON PLANT SELECTIONS, TOGETHER WITH MEAN, STANDARD DEVIATION, AND COEFFICIENT OF VARIABILITY (*After Dunlavy*)

Pairs of characters	Correlation	Number of plants	Mean	Standard deviation	Coefficient of variability
Staple.....	-0.445 ± 0.0419	167	32.2	1.31 ± 0.0484	4.08 ± 0.1498
Lint, per cent.....	39.39	1.10 ± 0.0405	2.79 ± 0.1028		
Weight, seed.....	0.426 ± 0.0428	167	12.98	0.813 ± 0.0300	6.25 ± 0.2300
Staple.....	32.2	1.31 ± 0.0484	4.08 ± 0.1498		
Weight, seed.....	-0.529 ± 0.0376	167	12.98	0.813 ± 0.0300	6.25 ± 0.2300
Lint, per cent.....	39.39	1.10 ± 0.0405	2.79 ± 0.1028		
Lint, index.....	8.43	0.45 ± 0.0166	5.34 ± 0.1965		
Staple.....	0.153 ± 0.0512	167	32.2	1.31 ± 0.0484	4.08 ± 0.1498
Lint, index.....	8.43	0.45 ± 0.0166	5.34 ± 0.1965		
Lint, per cent.....	0.203 ± 0.0501	167	39.39	1.1 ± 0.0405	2.79 ± 0.1028
Lint, index.....	8.43	0.45 ± 0.0166	5.34 ± 0.1965		
Weight, seed.....	0.704 ± 0.0208	167	12.98	0.813 ± 0.0300	6.25 ± 0.2300
Boll size.....	7.94	0.6 ± 0.0254	7.55 ± 0.32		
Staple.....	32.3	1.41 ± 0.0595	4.35 ± 0.1840		
Boll size.....	7.94	0.6 ± 0.0254	7.55 ± 0.3200		
Lint, per cent.....	-0.394 ± 0.0506	127	39.3	1.06 ± 0.0448	2.69 ± 0.1138
Boll size.....	7.94	0.6 ± 0.0254	7.55 ± 0.3200		
Weight, seed.....	0.664 ± 0.0338	127	12.96	0.8 ± 0.0339	6.17 ± 0.2610
Boll size.....	7.94	0.6 ± 0.0254	7.55 ± 0.3200		
Lint, index.....	0.480 ± 0.0461	127	8.39	0.415 ± 0.0175	4.95 ± 0.2094
Seed, per lock.....	-0.161 ± 0.0586	126	8.71	0.332 ± 0.0141	3.81 ± 0.1619
Staple.....	32.3	1.22 ± 0.0517	3.78 ± 0.1606		
Seed, per lock.....	0.099 ± 0.0506	126	8.71	0.332 ± 0.0141	3.81 ± 0.1619
Lint, per cent.....	39.5	1.12 ± 0.0476	2.83 ± 0.1204		
Seed, per lock.....	8.71	0.332 ± 0.0141	3.81 ± 0.1619		
Weight, seed.....	-0.149 ± 0.0587	126	12.9	0.804 ± 0.0341	6.24 ± 0.2652
Seed, per lock.....	8.71	0.332 ± 0.0141	3.81 ± 0.1619		
Lint, index.....	-0.082 ± 0.0596	126	8.39	0.456 ± 0.0193	5.43 ± 0.2308
Seed, per lock.....	8.63	0.299 ± 0.0169	3.46 ± 0.1962		
Boll size.....	7.76	0.473 ± 0.0268	6.09 ± 0.3453		
Per cent five-lock bolls.....	-0.109 ± 0.0555	144	41.8	15.85 ± 0.6288	37.89 ± 1.500
Staple.....	32.3	1.37 ± 0.0544	4.24 ± 0.1691		
Per cent five-lock bolls.....	41.8	15.85 ± 0.6288	37.89 ± 1.500		
Lint, per cent.....	39.3	1.09 ± 0.0435	2.77 ± 0.1095		
Per cent five-lock bolls.....	41.8	15.85 ± 0.6288	37.89 ± 1.500		
Weight, seed.....	0.114 ± 0.0555	144	12.94	0.789 ± 0.0313	0.610 ± 0.2420
Per cent five-lock bolls.....	41.8	15.85 ± 0.6288	37.89 ± 1.500		
Lint, index.....	0.0784 ± 0.0558	144	8.39	0.436 ± 0.0174	5.20 ± 0.2075
Per cent five-lock bolls.....	30.7	16.28 ± 0.9296	53.03 ± 3.028		
Boll size.....	7.75	0.513 ± 0.0293	6.62 ± 0.3780		
Per cent five-lock bolls.....	31.5	16.49 ± 0.9267	52.35 ± 2.94		
Seed, per lock.....	-0.045 ± 0.0720	72	8.64	0.304 ± 0.0171	3.52 ± 0.1978

Most of the correlations Dunlavy<sup>2</sup> gives are significant, and a number of them are of interest and of direct value. Among the most interesting, agriculturally considered, are: staple length and lint percentage, a rather high negative correlation being shown; weight of seed and length of staple, a rather high positive correlation (the lighter seeds here probably tended to be defective or undeveloped and had shorter staple); weight of seed and lint percentage, a high negative correlation, as was to be expected; lint index and weight of seed, high positive correlation; boll size and staple length, medium high positive correlation (the better developed bolls within the variety had better staple length); boll size and lint percentage, rather high negative correlation (the larger bolls had larger seed, hence lower lint percentage); boll size and weight of seed, high positive correlation; boll size and lint index, high positive correlation (the larger seed in the large bolls had more lint on individual seeds); per cent five-lock bolls and boll size, high positive correlation.

Table VII, adapted from Kearney,<sup>1</sup> shows significant correlations for a large number of characters. These data were collected from 182 second-generation hybrid plants of the Holdon  $\times$  Pima cross. Although this list of correlations is a long one, there are none that are between the same pairs of characters studied by Dunlavy. Comparison is, consequently, not possible.

The correlations in Kearney's list most interesting to cotton growers are boll length and fiber length, which gave a small positive correlation, and boll diameter and lint index, which gave a somewhat higher positive correlation.

Hodson<sup>15</sup> gives data on the correlation of characters of several varieties of cotton grown in Arkansas, namely, Trice, Foster, Express, Triumph, and all the varieties grown in the variety tests two different years. Data were collected on five different years. This work is interesting in that it shows much difference in correlation of the same pairs of characters when found in different varieties, or in the same variety in different years. In most instances the correlation coefficient was too small to be significant. Larger numbers might have given more consistent results for different varieties and perhaps for different years.

Among the most interesting of the significant correlations obtained by Hodson were the following:

1. Number of base limbs, and number of bolls per plant. This gave a positive correlation for every variety every year studied.

TABLE VII.—COEFFICIENTS OF CORRELATION IN THE SECOND GENERATION OF THE HOLDON-PIMA HYBRID WHICH ARE REGARDED AS SIGNIFICANT

Character pair	Correlation coefficient	Character pair	Correlation coefficient
Axis length and—		Corolla length and—	
Internode length.....	+0.831	Petal color.....	+0.214
Internode number.....	+0.715	Petal spot.....	+0.244
Fruiting-branch length	+0.620	Stamen length.....	+0.242
Fruiting-branch inter-node.....	+0.226	Pistil length.....	+0.470
Pedicel length.....	+0.218	Petal color and	
Fiber color.....	+0.178	Fiber length.....	+0.277
Internode length and—		Stamen length and—	
Internode number.....	+0.300	Anther color.....	-0.254
Fruiting-branch length	+0.596	Pistil length.....	+0.197
Fruiting-branch inter-node.....	+0.307	Boll diameter.....	+0.180
Leaf length.....	+0.199	Pistil length and—	
Pedicel length.....	+0.259	Lock number.....	-0.182
Internode number and—		Lock number and—	
Fruiting-branch length	+0.388	Boll diameter.....	+0.202
Fruiting-branch length and—		Boll length and—	
Fruiting-branch inter-node.....	+0.362	Boll diameter.....	+0.289
Pedicel length.....	+0.183	Fiber length.....	+0.175
Boll diameter.....	+0.182	Boll diameter and—	
Leaf length and—		Lint index.....	+0.214
Boll diameter.....	+0.205	Fiber length and—	
Pedicel length and—		Fiber color.....	-0.230
Bract length.....	+0.208		
Bract number of teeth	+0.187		
Bract length and—			
Boll length.....	+0.186		
Boll diameter.....	+0.187		

In 1917, when Foster cotton was used, the correlation coefficient was  $0.4348 \pm 0.0938$ .

2. Number of days from planting to open boll, and height of plant. This gave a positive correlation coefficient of  $0.4012 \pm 0.0817$ .

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## CHAPTER IX

### COTTON BREEDING

All efforts put forth to better or improve hereditary qualities of cotton plants may be considered cotton breeding. The cotton plant is susceptible of being changed or molded to fit a variety of conditions or to produce a varied product. The breeding or production of desirable varieties that yield well and have an excellent quality of fiber is a very important part of crop production.

**History of Cotton Breeding.**—It is impossible to say who was the first cotton breeder or where the work first started, as more or less work on cotton improvement has been carried on since early times. The Danish colonist Rohr mentioned by Watt<sup>1</sup> probably did some technical cotton-breeding work on the island of St. Croix about 1790. In his book, which was published at that time, he speaks of methods he used in the selection and hybridization of cottons. The introduction of Jumel's plant in 1820 (see Chap. II) may be considered the real beginning of cotton improvement work in Egypt. From that date until the close of the century, new or improved varieties were introduced from time to time, but distinct advances as a result of scientific breeding work were not made until after 1904.

Sea Island cotton was introduced into the mainland of North America about 1786. It is said that the plant at that time was perennial, larger than it is at present, and less productive. The growers early learned that by choosing the best plants, or the ones that best suited their needs, and propagating from them, they could grow more profitable crops. Consequently, they selected seed from the most compact, most productive plants, with the longest and finest staple, and have continued the selection ever since. As a result of this work, the plant was changed to an annual and made more productive, and the fiber was improved in length and character. But breeding work must be continued to hold the variety up to the high standard

of excellence that it has attained, that of being the finest cotton in the world.

Upland cottons were introduced into Virginia and other southern colonies soon after their founding. New varieties originated from time to time, and some good improvement work was done by a number of men interested in cottons, among whom J. B. Allen, of Port Gibson, Miss.; W. A. Cook, Newman, Miss.; John Griffin, Greenville, Miss.; T. J. King, Louisburg, N. C.; J. A. Peterkin, Forth Motte, S. C.; and J. R. Cleveland, Stratton, Miss., may be mentioned.

The year 1898 marks the beginning of scientific cotton breeding in the United States. That year Dr. Herbert J. Webber started cotton breeding for the U. S. Department of Agriculture. Methods in use by the growers of Sea Island cotton were studied, improved, and adapted to the breeding of Upland cottons.

Other breeding methods, which included hybridization and acclimatization, were developed. The majority of the most valued varieties grown at present were either produced by Dr. Webber or have been originated by some of his associates in the U. S. Department of Agriculture, or by his students.

Between 1900 and 1910 scientific cotton breeding was started by the Pedigreed Seed Company of Hartsville, S. C., and by Clemson College in South Carolina. The Mississippi Agricultural Experiment Station started breeding work in 1910, and since that time experiment stations in several other states have started similar work. Several commercial seed-breeding plants have also been established. Many of these do careful breeding work and put out a supply of well-bred seed. These seed companies are especially helpful to the cotton growers, because they produce and make available quantities of pure, high-class seed. The U. S. Department of Agriculture and the state experiment stations originate good varieties and grow a small amount of good seed, but they lack facilities for producing good seed in quantity.

**The Object of Cotton Breeding.**—As was pointed out in Chap. VIII, many of the varieties of cotton grown at the present time are of hybrid origin, or constitution, and are consequently subject to much variation. Many of the varying forms produced are inferior, and they cause a general deterioration of the whole population of plants. Breeding work is necessary to hold varieties up to their present standard or condition, to say nothing of improvements. There is room for definite improvement in the

character or qualities of all cottons. They may be changed so as to be better adapted to the environmental conditions where they are grown; they may be made earlier; the yield may be increased; the lint percentage improved; the lint improved in spinning qualities and length; the lint may be improved in uniformity on the various plants of the variety, on different parts of an individual plant, or even on different parts of an individual seed; the form of plants may be improved; bolls may be made larger and other picking qualities improved; storm resistance may be increased without interfering with the picking qualities; many varieties need to be made more disease-resistant, especially more resistant to wilt and anthracnose. It is not to be expected that any one variety can be improved along all lines or made to approach perfection in every respect. There are apparently some antagonistic qualities, as were pointed out by Duggar.<sup>2</sup> Plants that have unusually large bolls cannot be extremely early; varieties with long staple will not have high lint percentage; extreme earliness is opposed to high lint percentage; a high lint percentage is seldom found in varieties that have large seeds. To the list of opposed qualities mentioned by Duggar may be added wilt resistance versus extreme earliness and prolificness. Some of the semiresistant varieties are early or medium early, but none of the regular resistant varieties are early.

**Cotton-breeding Methods.**—Three different types of work are carried on by persons seeking to make improvement in cotton plants, or, in other words, in cotton breeding. These are selection, which consists in searching out and propagating from certain outstanding plants; hybridization, the essential part of which consists in crossing different races with the idea of combining in one plant desired qualities found in different plants; and acclimatization, which consists in transferring strains or varieties from one region to another and growing them in the new habitat long enough for them to become adjusted to it or acclimated. Each of these methods will be discussed separately and in some detail. (This discussion of cotton breeding applies particularly to American Upland cotton.)

**Cotton Breeding by Selection.**—The selection method of cotton breeding is used more than any other method, and probably better results have been secured with it than with any other. The other methods, hybridization and acclimatization, also include selection work and would not be successful without it.

**Mass Selection.**—Mass selection is the simplest type of selection and is one of considerable value to the cotton grower who wishes to do some improvement work on his cotton but does not have the opportunity to do more complicated breeding work.

The cotton grower who wishes to do mass selection work goes into his cotton field about the first of September, or after there are some open cotton bolls on nearly every stalk, and tags a large number of what he considers good stalks. He must have in mind a definite type of plant, size of boll, length of staple, etc., and choose only plants that make a near approach to his ideal. Furthermore, he must hold to the same ideal year after year to make progress. After the bolls on the tagged stalks are all open, they are picked, the cotton from all being put together. This seed cotton must be so ginned that there will be no mixing with other seed. This can be done easily by feeding the cotton by hand into one gin of a large ginnery and catching the seed on the floor in front of the gin. These seed should be planted the following year in a seed patch isolated from other cotton. The land should be good so that the quantity of seed produced will be large, and the plants should be widely spaced so that each plant will have a chance to show its individuality. New selections should be made in this patch for planting the next year's seed patch. The rest of the seed grown can be used in planting the general crop.

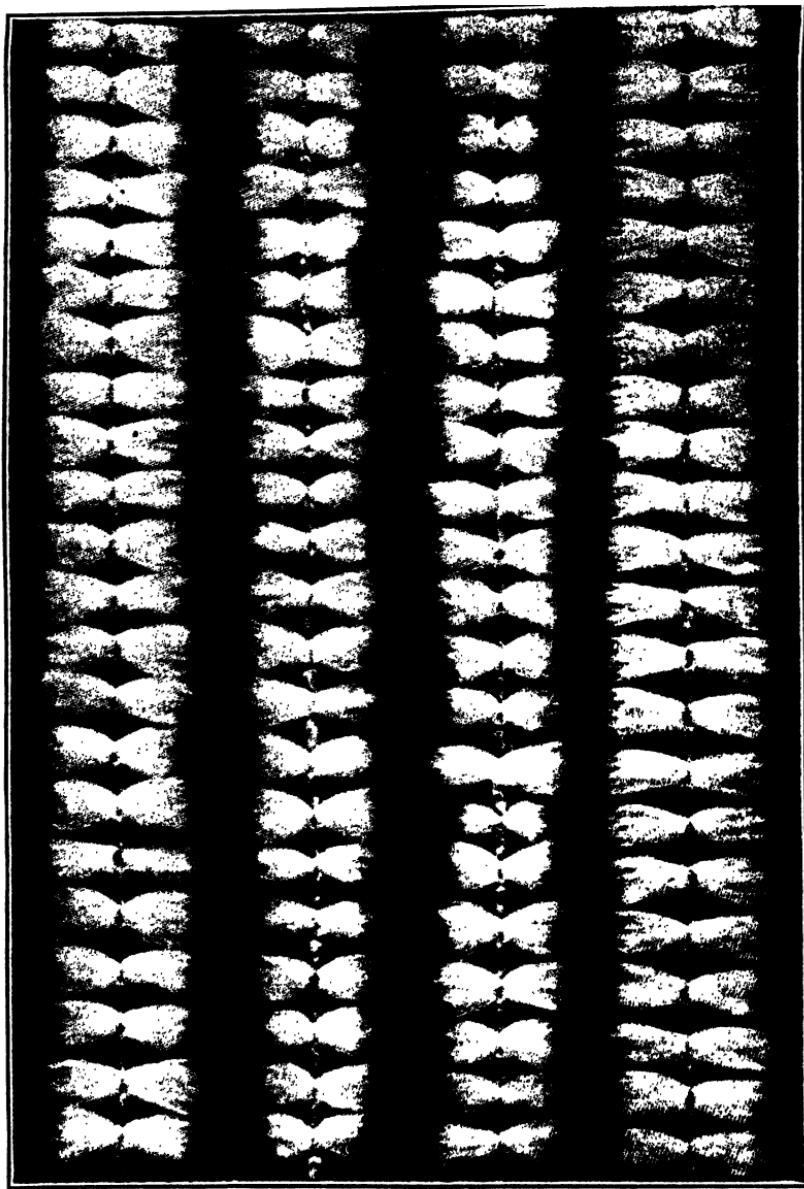
By continuing the plan outlined for a series of years, a fairly uniform strain of cotton may be produced. Sunflower, at one time one of our leading long-staple cottons, was produced in this way by Mark Schaeffer, of Yazoo City, Miss. He started with mixed seed obtained from an oil mill. Cleveland Big Boll is another important variety developed by mass selection. While this plan will give results eventually, it is slower than other methods. A disadvantage of the method is to be found in the fact that a part of the fine-looking plants chosen are first-generation hybrids which will not breed true the next generation. Other good-looking plants fail to transmit their good qualities, and their seed becomes mixed with seed of the better plants.

**Individual Plant Selection.**—The selection of individual plants followed by plant-to-row testing is the plan usually followed by plant breeders. In looking for outstanding plants to select, the breeder starts work as soon as the cotton has begun to open freely, and walks over large fields, row by row, of the variety

with which he has decided to work. Chances of success are better if the land is rich, and the plants are well fruited and spaced far enough apart for each plant to develop well. The breeder surveys two to four rows as he walks along. Any plants that, at first glance, appear promising are examined in some detail; their characteristics are noted, lint combed out so that its length may be judged, and the lint percentage roughly estimated. A person that has had some practice can usually estimate to within 2 per cent of the correct lint percentage. Only a few plants are found each day that measure up to the requirements in mind. These plants are carefully tagged, and it is the writer's practice to write on the tag a brief description of the plant chosen. Later when the bolls are all open, the plants are picked separately, the seed cotton of each being put in a paper bag, along with the descriptive tag that was on the stalk.

The outstanding plants chosen in making selections fall into three classes: (1) Exceptionally well-formed and well-fruited typical specimens of the variety with which the breeder is working. If the variety is relatively pure or well bred, this class will include most of the selections made. (2) Plants which contain good character combinations which are segregates of characters from hybrid ancestors. (3) Mutants, which are striking new forms that have appeared, and which have certain characteristics not possessed by the parental strain.

*Plant Characters Observed When Making Selections.*—As a cotton breeder walks along a row of cotton looking for superior plants, certain characters of the plants hang out as sign boards to attract attention. Of these the most conspicuous is *prolificness*, or amount of fruit on the plant, and it is probably the most important character to consider in making a choice. Other desirable qualities that the breeder of Upland cotton looks for are *compactness* of plants, *low branches*, and *short internodes* (plants with extremely short internodes in branches such as are found in the cluster varieties are not desirable); *light foliage*, which is especially desirable in humid regions, or in regions of heavy boll-weevil infestation; *fair-sized bolls* (small-bolled cottons are more prolific and may yield more but are harder to pick); *freedom from disease*; *satisfactory lint length*; *satisfactory lint percentage*; and *good picking qualities*. With some varieties and with certain species of cotton the branching habits are of considerable importance. Leake<sup>3</sup> has shown that certain races



*Selected Stock      Unselected Stock      Unselected Stock      Selected Stock*  
*Combed Samples from Consecutive Plants*

FIG. 43.—Samples of lint, showing the effect of selection on the uniformity of Meade cotton. The two center rows show combed lint from consecutive plants in the original unselected stock. The two outside rows show combed lint from consecutive plants in selected stock. Note the uniformity of fiber and seed in the selected stock as compared with the irregularity of both fiber and seed in the unselected stock. (After Meloy and Doyle.)

of Indian cottons bear cotton blooms only on sympodial branches. If the secondary branches the plant produces are sympodial, blooms will be formed early; but if the secondary branches are monopodial, flowers will not be formed until the tertiary branches appear, which are sympodial. This makes the flowering much later. Varieties with this type of branching are not suited to the more northern portions of the cotton belt in India. Among the Upland varieties, plants with more than three or four vegetative branches are to be avoided. Figure 11 shows a good type of Upland cotton plant.

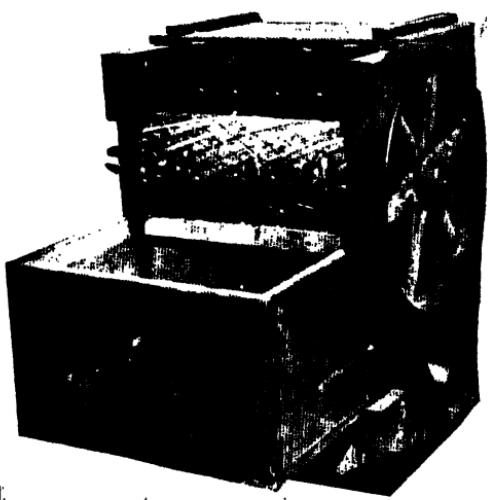


FIG. 44.—A small roller gin for ginning cotton from individual plants. (After Childs.)

*Testing Selections.*—After the selected plants are picked as was explained above, they are taken to a laboratory or some suitable place, where the cotton lint is combed out, as shown in Fig. 43, and measured. The seed cotton from each plant is ginned by itself on a small gin, either a ten-saw saw gin, or a small roller gin made for the purpose (see Fig. 44), and the seed saved. Most breeders weigh the seed cotton and seed from each plant and then compute lint percentage. All the notes and data on each plant are recorded on pedigree cards or sheets and preserved.

The following season the seed from the selections is planted in a plant-to-row test. If seed is plentiful, two short rows may be planted. If these are planted in different parts of the breeding

block or cut, it adds to the value of the test. If a strain does well in two places, the chances are greater that it has merit. The seeds must be planted by hand, preferably in hills about 2 feet apart, and in rows 100 to 200 feet in length. To insure a good stand not fewer than ten seed should be planted in a hill. At thinning time the plants should be thinned to one in a hill. It is desirable to plant seed from plants with similar characters in adjoining rows.

During the growing season the different strains in the progeny rows are observed from time to time and note made of marked peculiarities. In the fall after all the bolls have opened, the rows are studied in detail and notes made on each. Each row is picked separately and the cotton weighed. On basis of this yield weight and the other data gathered a small percentage of the best strains is saved, usually 5 to 10 per cent. The others are discarded or saved for planting in the general crop. If the poorest of the rows are discarded and the seed from the others massed, it makes a good quality of seed to plant, considerably better than seed from simply mass-selected plants, because the poorer strains have been eliminated from this.

The second year after the original selection is made, a portion of the seed from each of the choice progeny-row strains that were saved is planted in another test, which is sometimes called a "new-strains test." This test is handled in much the same way as was the progeny-row test discussed above, except that, as more seed is available, the rows may be planted with a planter. Besides being more rapid than hand planting the planter places the seed more uniformly if the land is in good condition. A planter with a hill-dropper attachment and a roller wheel behind to regulate depth is to be preferred. Since more seed are available it is possible to have more replication of rows. It is the writer's practice to have four series in the test, which means that there are four rows of each strain. These are in different parts of the test plats, and afford a more reliable trial than would a single row.

Results from the "new-strains test" will show clearly any strains that have special merit. If any such have appeared (in most instances they have not), the progeny-row remnant seed, that is, the rest of the pure seed saved from the progeny row, is planted in an isolated patch the following year and a start made to increase the strain. If seed are available, it is a good

plan to put the few strains that were outstanding in the "new-strains test" in a variety test the following year, where they may be compared with standard commercial varieties. If they are not an improvement over the varieties already in use, they should be discarded. Seed from the "new-strains test" may be planted in the variety test.

*Increase Fields.*—As a result of the three tests—progeny-row, new-strains, and variety—the merits of new strains are determined rather conclusively. Any strains that have ranked



FIG. 45.—Roguing Meade cotton. (After Meloy and Doyle.)

comparatively well the three years must be worthy of multiplication and should be increased as rapidly as possible. The remnant of pure seed saved from the progeny row should be planted on good land in a field isolated from other varieties of cotton as far as is convenient. A barrier of at least twenty-five rows of corn or of some other crop should be used. The seed should be made to plant as great an acreage as is possible. The increase plats or fields should be inspected row by row at least twice each season for the first two seasons and all off-type plants rogued out, or pulled out. In so far as is practicable to do so, all fields from which seed is to be saved for planting purposes, should be rogued (see Fig. 45).

*Practical Results from Selection Work.*—If the origin of the leading cotton varieties being grown at the present time is studied, it is found that most of them have arisen from plant selections, the product of simple selection work, or selection work combined with hybridization or acclimatization. Lone Star, Mebane's Triumph, Delfos, Dixie, Half and Half, Webber, Pima, and others were produced by straight selection work. Foster, Salsbury, Culpepper, and some others come from selection combined with hybridization. Acala, Durango, and Express are the result of acclimatization combined with selection work (see Chap. III for further details concerning the origin of varieties).

Through or by means of selection, various characters of cotton plants may be made much more uniform. This is especially true of the important character of lint length. The effect of selection on this character is well shown by Meloy and Doyle<sup>4</sup> in work with Meade cotton (see Fig. 43).

Pima, an American-Egyptian variety, arose from a single remarkable plant which was probably a mutant. It gave a progeny of comparatively uniform plants, and all of its descendants have been more uniform than is usually found among cotton progenies, yet Kearney<sup>5</sup> has shown that the strain was susceptible of change when subjected to selection and roguing for 7 years. The fiber was increased in length 3.8 millimeter, or more than  $\frac{1}{8}$  inch; the amount of lint on 100 seeds was raised approximately 1 grain; and several other slight heritable variations were observed. A new strain arose within one of the progenies which lacked the petal spot found on most Pima plants, and had a higher percentage of four-lock bolls. The selection work on Pima cotton during the 7 years was apparently not sufficient to reduce the strain to gametic purity. It was consequently still susceptible to change by selection.

**Cotton Breeding by Hybridization.**—The primary object in hybridization, or cross-breeding, is to combine in one individual qualities normally found in different individuals. A secondary object is to disturb the equilibrium of the variety so that there will be more variation, thus facilitating selection by making the variety of forms or character combinations greater. Some authorities believe that mutations are more common in strains which have a hybrid ancestry.

Although selection is considered the most effective method in cotton breeding, it is probable that hybridization assists indi-

rectly in many instances. It is impossible to say how many of the outstanding plants that are selected owe their good qualities to the segregation of characters in hybrids produced by natural crossing that took place years before. As has been shown by Johannsen, and others, selection within a pure line has practically no effect. If cotton strains are line-bred, or inbred until they approach genetic purity, selection probably will have but little effect. Cross-breeding is thus a necessary prerequisite, even if several years removed, to most effective selection work. The fact that a character may be transferred from one variety to

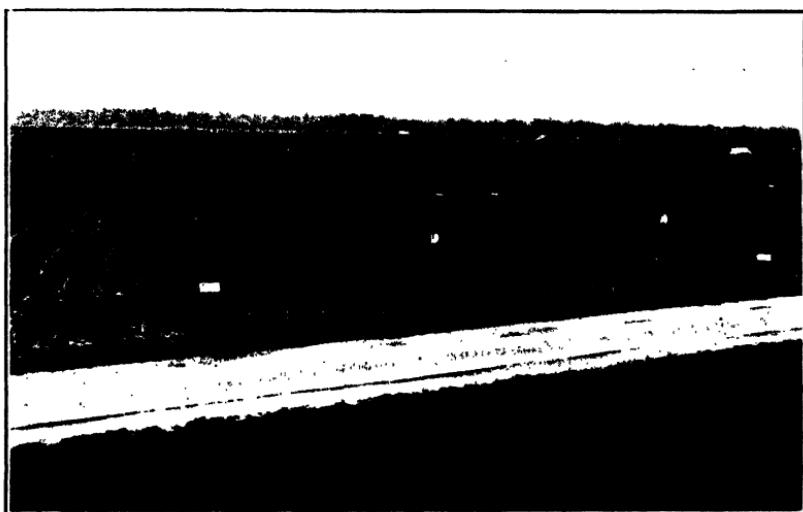


FIG. 45a.—Breeding plats and trial grounds of the Stoneville Pedigreed Seed Company, Stoneville, Miss.

another by crossing makes this type of breeding promising, even if it is usually very difficult to get just the combination of characters wanted in a fixed or stable race of plants.

*Limits of Hybridization.*—All American Upland varieties will cross with each other, and they will also cross with Sea Island and Egyptian varieties, but will not cross with certain Asiatic varieties belonging to the species *G. herbaceum* and *G. arboreum*. Sea Island and Egyptian varieties will cross with each other, but probably will not cross with the Asiatic varieties mentioned. Certain of the Asiatic varieties and species will hybridize.

**Manipulation of Flowers in Artificial Cross-breeding.**—Cotton flowers are easily cross-pollinated, because the flower parts are

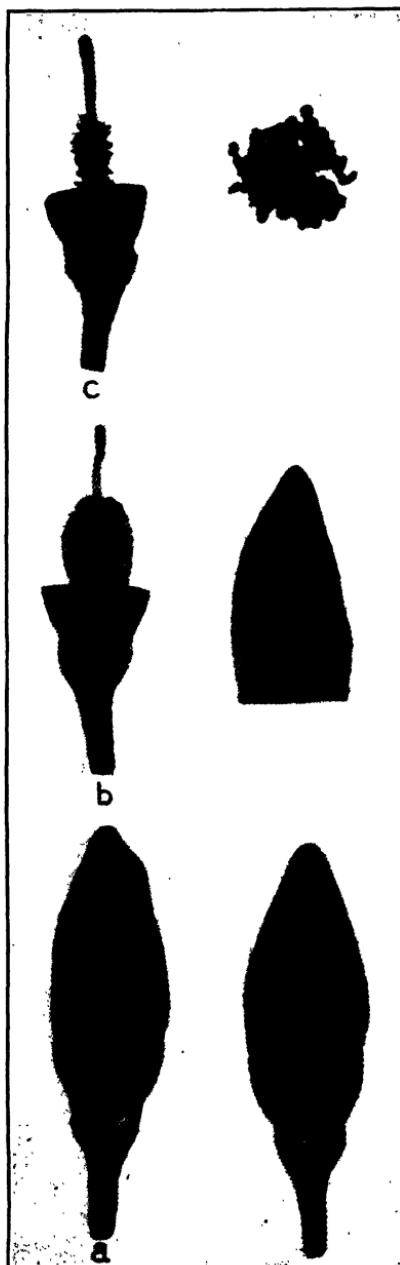


FIG. 46.—Flower buds of Pima cotton. The successive stages of the process of emasculation during the evening preceding anthesis: Intact buds (a); bud with corolla removed, showing the tightly closed anthers (b); anthers removed, flower ready for pollination (c). (After Kearney.)

large, pollen is abundant, the stigma is large and receptive, and the plants are normally susceptible to cross-breeding. If a cross is to be made on a certain day, during the afternoon of the day previous the breeder chooses for emasculation certain flower buds that are scheduled to open the following morning. These may be recognized from the enlarged, yet twisted and folded, corolla (see Fig. 46A). The corolla is removed with the small blade of a knife or a scalpel, leaving parts shown in Fig. 46B. The anthers, or male part of this flower, are next removed, either by scraping them off or peeling off the filaments with anthers attached. The anthers contain pollen and should not be broken lest the pollen be scattered over other flower parts. It is not safe to use a flower in which the anthers have begun to open. After the anthers are removed, the flower presents the appearance of Fig. 46C and is said to be emasculated. Only the pistil, or female part of the flower, is left. The stigma is the club-shaped portion at the top.

A small paper bag is next tied over the emasculated flower bud and left until the next day. To provide a supply of pure pollen, bags are tied over similar flower buds on plants of the variety that is to be crossed on the first. By nine o'clock of the following day, if the sun is shining, the emasculated flower will be ready to be crossed. The stigma will appear sticky and, in fact, is coated with sirup-like substance to which pollen grains will adhere and in which they will germinate. A whole flower is removed from the plant that is to furnish the pollen. The anthers in this flower will be open by this time, showing a mass of yellow pollen. The brush of anthers is rubbed against the stigma of the emasculated flower. If the work is well done, pollen can be seen on the stigma. The paper bag is again tied over the crossed flower to keep away insects, and left at least 2 or 3 days. It will do no harm to leave it on until the resulting boll opens. This may serve to keep boll weevils from the boll. After the cross is made, it is, of course, necessary to attach a tag to the flower, so that the boll may be distinguished later.

If the crossing work is carefully done, and is done fairly early in the blooming season, the period when shedding is lowest, a high percentage of the crosses will be successful, say 75 per cent or more.

**Viability of Pollen.**—Work by Kearney<sup>13</sup> showed that pollen of both Upland and Egyptian varieties (Durango and Pima)

was most viable between the hours of 10 a.m. and 2 p.m. By 6 p.m. only 3 or 4 per cent of the grains seemed to be alive. Pollen from flowers enclosed in paper bags all day was still nearly normal at 6 p.m. A fair percentage of the pollen grains was still viable at 6 a.m. the next morning. The writer has found the pollen of various Upland varieties to be very satisfactory for use in the afternoon of the day the flower opened, provided the flower had been bagged.

**Fertility of Bagged Flowers.**—In breeding work it is often desirable to have seed from many self-pollinated plants. To self-pollinate by hand is burdensome if there are many plants. It has been found that, if flower buds are enclosed in small paper bags the day before opening, they will be self-pollinated and a fair percentage will set bolls. Kearney<sup>13</sup> reports more than 90 per cent as compared with normal open-pollinated flowers, but the number of seeds in a boll was considerably lower in the selfed bolls. In work carried on by the writer, not more than 50 per cent of the bagged flowers made bolls, but some of the failures were due to natural shedding.

**Natural Crossing in Cotton.**—Different varieties of cotton are very frequently planted in close proximity, as, for instance, in adjacent fields. In nearly every locality there are bees, butterflies, and various other insects that visit the cotton flowers and may carry pollen from one field to the flowers of plants in another, thus bringing about cross-pollination and hybridization. This, as has been shown elsewhere, has been partly, if not largely, instrumental in causing our cotton varieties to contain many hybrids, to be impure, and to deteriorate freely.

In breeding work and in practical cotton growing, the question often arises as to what percentage of crossing takes place between two varieties of cotton when planted side by side in a field, in adjoining fields, or when separated various short distances. Considerable experimental work to obtain data in answer to these questions has been carried on by Webber,<sup>6</sup> Balls,<sup>7</sup> Allard,<sup>8</sup> Shoemaker,<sup>9</sup> McLendon,<sup>10</sup> Brown,<sup>11</sup> Leake,<sup>12</sup> Kearney,<sup>13</sup> and others.

Webber,<sup>6</sup> from his experiments in South Carolina and in other southern states, estimated that there was from 5 to 10 per cent of crossing between different varieties of Upland cotton when grown in adjacent rows. Allard<sup>8</sup> found that, when Keenan and Okra Leaf, or Red Leaf cottons were planted in alternate

rows in northern Georgia, 20 per cent of the bolls on the Keenan cotton were hybridized. The seed of these bolls produced a varied number of hybrid plants, ranging from one to as many as there were seeds.

Ricks and Brown,<sup>11</sup> in experiments carried on at A. and M. College, Mississippi, found that when green-leaf varieties were planted in rows alternating with rows of Willett's Red Leaf, 4.9 to 11.1 per cent of the ovules were crossed. The percentage varied slightly with the different green-leaf varieties. The percentage of crossing on Trice and Lone Star-132 was lower than on Triumph, Cleveland, and Lone Star-15. This was doubtless due to the fact that the first two varieties were slightly earlier than the red-leaf variety and did a larger percentage of their blooming early in the season. Individual boll progenies of Trice showed that 36 per cent of the bolls were hybridized to some extent; and 44 per cent of the Lone Star-15 bolls were hybridized. But few of the seeds in any one boll were hybridized; the number ranged from one to nine.

When the varieties mentioned were planted in alternate hills in alternate rows, the crossing was 18.5 per cent. In a plat where a green-leaf variety was separated from the red-leaf by a barrier of ten rows of corn, two crossed plants were found in a progeny of 244 plants. This gives a moderately high percentage, considering the position of the two varieties. If a larger number of plants had been grown, the percentage might have been lower. The two crossed seed from which the two hybrid plants were grown were probably the result of a single insect visit to one of the hundred bolls gathered for seed.

In other natural crossing experiments conducted by the writer at A. and M. College, Mississippi, in 1918 and 1919, Winesap cotton, a red-leaf variety slightly earlier than Willett's Red Leaf, was planted in various positions with respect to green-leaf varieties. Fifty or more stands of honeybees were kept within a half mile of the experimental plats. Many honeybees visited the flowers; 112, according to actual count, entered a single flower during the first day it was open. Counts of progenies from bolls on rows next to a red-leaf row showed 3.9 to 5.6 per cent crossing; second rows from the red-leaf row showed from 0.68 to 0.78 per cent; third row, 0.4 per cent; fourth row, 0.51 per cent; fifth row, 0.78 per cent; sixth row, 0.17 per cent; seventh row, 0.14 per cent; eighth row, 0.19 per cent; ninth row, 0.00

per cent; tenth row, 0.00 per cent; eleventh row, 0.00 per cent; twelfth row, 0.00 per cent.

In 1919, twenty-seven rows of Winesap cotton were planted at one end of a cut, and the rest of the cut was planted in Cleveland, a green-leaf variety. That year there was much more crossing, due probably to the larger number of plants grown.

The figures ran as follows:

Bolls from the green-leaf row next to the Winesap rows produced 14.8 per cent hybrid plants; second row, 6.5 per cent; third row, 6.9 per cent; fourth row, 4.0 per cent; fifth row, 3.2 per cent; eighth row, 1.3 per cent; tenth row, 1.9 per cent; sixteenth row, 0.6 per cent; twentieth row, 0.5 per cent; twenty-fifth row, 0.4 per cent; thirteenth row, 0.17 per cent; thirty-fifth row, 0.12 per cent; fortieth row, 0.23 per cent; fiftieth row, 0.00 per cent; sixtieth row, 0.05 per cent; seventieth row, 0.24 per cent; eightieth row, 0.00 per cent; ninety-fifth row, 0.06 per cent; one hundred and fourteenth row, 0.06 per cent; one hundred and nineteenth row, last row in the cut, 0.00 per cent.

Four green-leaf plants grown at different points in the red-leaf plat had more than 50 per cent of their ovules crossed. The numbers were 57.1, 66.2, 81.4, and 61.7 per cent.

Data obtained by other investigators have not varied greatly from that given on the foregoing pages. McLendon<sup>10</sup> in Georgia observed 1.9 per cent crossing between adjoining rows; Shoemaker, 10.9 per cent in Texas; and Kottur, 6 per cent in India.

The data presented show that the amount of crossing that takes place between two varieties only a few yards apart is limited, yet there is some, and there may be some crossing between fields a quarter or a half mile apart. The only practicable way to prevent this very limited amount of crossing is to grow only one variety in a community.

The percentage of crossed seed depends on: (1) The relative rate of blooming of the neighboring varieties. (2) The position of stigma and stamens in the flower. As Kearney<sup>13</sup> has shown, the flowers of some varieties are especially adapted to cross-pollination, and the flowers of others are better adapted to self-pollination. (3) The relative abundance of insects. Insects are much more abundant in some regions than in others, but difference in number does not appear to make a corresponding difference in cross-pollination. In natural crossing experiments made by the writer in the Mississippi Delta in 1918, where insects

were very much less abundant than at A. and M. College, not more than two or three visiting a flower in the course of a day, practically as much crossing was obtained as at A. and M. College in similarly conducted experiments.

**Characteristics of Hybrids.**—First-generation hybrids are frequently larger, more vigorous, and more productive than their parents (see Table IV, in Chap. VIII). Many of them are very interesting and very promising, but no great amount of importance can be attached to them because they are not likely to reproduce their valued qualities.

In the second generation, as has been mentioned in Chap. VIII, there is a breaking up of types and a segregation of characters into many combinations, but by far the larger part of these are worthless from an economic point of view. The breeder selects a few plants in the plat that make the nearest approach to his ideal and grows their progenies in a plant-to-row planting the following year. Some of these will segregate further, but some few may breed true for certain desired character combinations. Further selections may be made in the third and later generations, but the chances are that nothing will ever be secured that is very satisfactory. Only one cross in many proves to be of high value.

If the first cross does not yield anything satisfactory, it may be worth while to cross the hybrid with one of the original parents. Plants grown in third and later generations continue to break up and do not differ greatly from the ones grown in the second generation.

**Results from Hybridization.**—As may be seen from the preceding discussion, it is a very simple matter to cross-breed cottons and it is a comparatively easy matter to secure desirable types in the first generation; but it is a task to secure the wanted character combinations in types that breed true in later generations. Notwithstanding this difficulty, several good varieties have been produced in this way, notably Salsbury, Foster, and Sun-press (see Chap. III). Still other good varieties have been produced by selection in varieties that were hybridized many years before, or by the selection of mutants in strains of hybrid ancestry.

Although, as has been shown, uncontrolled hybridization is the cause of much deterioration in cotton, it is also probably true that maximum yields are due to hybridization in many

instances. Certain varieties appear to have dropped in comparative yields after being subjected to close selection for 10 years—selection that made them more uniform and tended to reduce them to genetic purity. Two strains of Express grown by the writer which were self-pollinated and linebred for 3 years, when crossed, gave a progeny in which the plants were larger than their parents, produced more flowers, and yielded more cotton. Leake and Prasad, in India, found that certain cottons of the Asiatic type retained fewer bolls, comparatively, if inbred one or more generations, but that later crossing tended to overcome this effect. Kearney,<sup>13</sup> in careful experiments performed with Pima cotton in Arizona, found that

. . . inbreeding during seven generations brought about no reduction in the daily rate of flowering, in the percentage of bolls retained, in the size, weight, and seed content of the bolls, in the weight and viability of the seeds, or in the abundance of the fiber, as compared with those of the continuously open-pollinated stock. It is concluded that the deleterious factors had been eliminated in the ancestry of the Pima variety and that its present state of fertility is due to segregation rather than to heterosis.

Further experiments conducted by Kearney<sup>13</sup> showed that in Pima and Acala cotton a large proportion of the pollen deposited on the stigma of a flower comes from the anthers of the same flower, either being transferred by insects or deposited mechanically by the flower itself. It may be inferred from this that a large percentage of cotton ovules are naturally self-fertilized.

**Results from Acclimatization Work.**—Certain cotton varieties are especially adapted to a given set of conditions, but not well adapted to many others. Todd<sup>14</sup> notes that many of the finer Egyptian varieties in Egypt are at their best only in particular limited districts.

By transferring varieties from one region to another and growing them in the second for a number of years, or until they become adjusted to the new environment, certain new types may be found which are of unusual value to the second region.

When a cotton is transferred from one region to another with different environmental conditions, as from the American Cotton Belt to China, for instance, the first crop grown produces well

and is satisfactory. If grown longer it seems to be the tendency for the variety to "go to pieces," as it is termed. Many off-type or worthless plants appear and deterioration is rapid. Griffing<sup>15</sup> found this to be true for Trice, Acala, Miller, and College No. 1 taken from the United States to China (see Fig. 47). If selections are made within the variety and new strains built up in this way, the results will be satisfactory and well-adapted cottons may be obtained. Trice handled in this way has given Griffing<sup>15</sup> very satisfactory results in regions to which it is suited. In coastal regions it was found to be inferior to native cottons.

It appears that the removal of cottons to new environmental conditions not only stimulates the plants to extreme variation

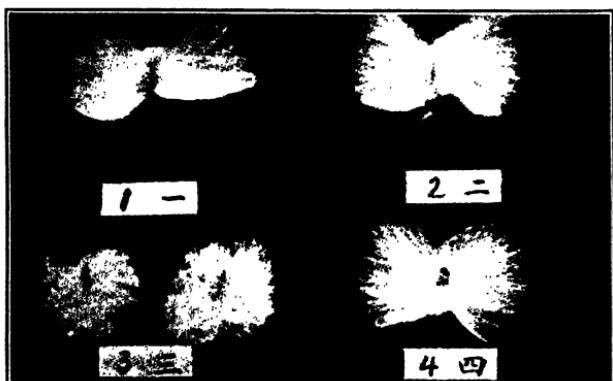


FIG. 47.—Numbers 1 and 2, American cotton from seed just imported. No. 3, degenerate American cotton from seed grown in China only three years. No. 4, Chinese cotton from selected seed. (After Griffing.)

and the production of many inferior forms, but also produces some exceptionally good types. Griffing noticed some of these in both the Acala and Trice varieties with which he was working in China. Kearney made similar observations on the Egyptian cotton with which he was working in Arizona. The Pima, Yuma, and one or two other less known varieties sprang from these variant forms found in fields in Arizona.

**Results from Acclimatization Work in America.**—During the 300 years that cotton has been grown in the American Cotton Belt, cottons have been imported from nearly every part of the world that grows cotton. Many of these importations were, of course,

complete failures; other cottons imported were probably crossed with American varieties and lost their individuality but left their impress; still others imported were found to be desirable and adaptable to certain regions, and were preserved. Sea Island, Egyptian, Acala, and Durango belong to the latter class. Sea Island was imported more than a century ago, selected and acclimatized to the conditions prevailing in Georgia and South Carolina, and made the best long-staple cotton in existence. Egyptian cotton was imported and grown experimentally by the U. S. Department of Agriculture in irrigated valleys of South Arizona in 1902. As the climate of that region resembles that of Egypt, it was thought that a cotton adapted to Egypt might do well there. Several Egyptian varieties and strains were tried. The Afifi variety gave better results than any other; so the others were dropped. The method of selection and progeny-row testing was followed for several years without much gain apparently. In 1908, a superior and distinct new type appeared which indicated a real advance and gave rise to the variety Yuma. This was followed a little later by another still better new form which gave rise to the Pima variety. This proved so good that it was increased as rapidly as possible and introduced commercially. It soon largely displaced other Egyptian varieties in Arizona and California.

**Acclimatization of American Varieties in Foreign Countries.**— Since American varieties of cotton are superior in yield and lint characters to many of the native varieties of other countries, many importations of American varieties have been made.

About 1840, the East India Company, in order to foster the growing of American cotton in India, not only imported seed but employed ten American cotton growers to go to India to introduce American methods of culture. This plan met with but very little success, and the Americans soon returned home. The Dharwar American cotton grown about the town of Dharwar in the Bombay Presidency is from some of the American cotton imported at that time, and marks one of the few successful attempts at introduction. Cambodia, or Tinnevelly American, probably the most valuable cotton grown in India, is also of American origin.

Failure has resulted in most cases when American cottons were taken to other countries because the cotton was not handled

properly. It was allowed to become mixed with local varieties, and few if any attempts were made at selecting better-adapted strains that appeared the first few years after introduction, or during the usual period of deterioration. Within the past few years certain American varieties have been successfully introduced into parts of China by Griffing,<sup>15</sup> who used modern methods of cotton breeding. American cottons have been introduced into Chosen (Korea) by Japan and are apparently being grown successfully. Brazil, Argentina, and other South American countries are now introducing American Uplands.

**Breeding Cotton Varieties for Wilt Resistance.**—Distinct advances in one type of cotton breeding, that of breeding strains resistant to cotton wilt, a disease caused by *Fusarium vasinfectum*, Atk., have been made comparatively recently by W. A. Orton and his associates in the Bureau of Plant Industry, U. S. Department of Agriculture, and by A. C. Lewis and others in Georgia and Alabama. New varieties developed may be grown profitably on land badly infected with wilt. In breeding for wilt resistance the usual method of selection and plant-to-row testing is followed, the only difference being that all the work is done on wilt-infected soil.

**Judging Cotton Plants.**—It is comparatively difficult to judge the relative merits of different varieties of cotton when individual or a few plants are offered in an exhibit. Certain plants grown under very favorable conditions may appear much better than others grown under slightly less favorable conditions, but would appear at a decided disadvantage if the two were put in a field side by side. As has been shown by recent research, larger yields per acre may be obtained if plants are closely spaced in the row, and the most desirable variety is the one that will yield the most cotton when so planted; yet the individual plants of the variety, especially if grown under close spacing conditions, may make a poor showing in the exhibit room. The important considerations are quantity and quality of lint produced per acre. Certain general characteristics of cotton plants that are considered desirable, however, and the degree of their expression may be judged in a cotton exhibit. Exhibits stimulate interest in growing better cotton and are educative to some extent.

The following score card, adapted from Bulletin 294 of the U. S. Department of Agriculture, may be used in judging cotton.

## SCORE CARD FOR THE COTTON PLANT

PERFECT  
SCORE

Plant form.....	25 points
Size: medium to large, as influenced by soil, location, season and variety.....	5
Form: symmetrical, spreading, conical to rounded, height and spread according to variety, soil, season, etc.....	5
Stalk: minimum amount of wood in proportion to fruit.....	5
Branches: springing from base, strong, vigorous, short-jointed.....	5
Head: well branched and filled, fruited uniformly.....	5
Fruiting.....	25 points
Bolls: abundant, uniformly developed, plump, sound, firm, and well rounded.....	5
Number of bolls: according to variety, soil, and season.....	5
Bolls per pound of seed cotton: big-boll varieties, 45; medium-sized bolls, 60; long-staple varieties, 70.....	5
Picking qualities (the perfect boll has large, stiff protruding locks that cling together and are easily removed from the boll).....	5
Storm resistance (the perfect type has drooping bolls, which have large, stiff burs that hold the locks well and act as a shed over the locks below, but spread apart, so that they do not interfere with picking).....	5
Yield.....	29 points
Seed cotton per acre (standard 1 bale per acre).....	12
Per cent lint (40 per cent standard for short-staple varieties and 32 per cent for long-staple).....	12
Seeds: forty-five per boll, plump, color according to the variety, and germination not less than 95 per cent.....	5
Length and character of lint.....	21 points
Strength: tensile strength good and uniform throughout.....	5
Length: standards, short-staple, 1 inch; benders, $1\frac{1}{4}$ inches; long-staple, $3\frac{1}{6}$ inches or longer.....	5
Character of staple: fibers fine, soft, silky, and of good spinning quality.....	5
Uniformity: all fibers of equal length, strength, and fineness.....	5
Purity: fiber white and free from stain, dirt, and trash.....	1
Total points.....	100

**Deterioration of Cotton Varieties.**—As has been shown elsewhere, and as everyone who has grown cotton any length of time knows, cotton varieties will deteriorate in yield and in other qualities unless some effort is made to prevent it. As cotton is commonly grown and handled, there is crossing between different varieties in adjoining fields and much mixing of seed at the gin. Sanders and Cardon, in Texas, found that, if the roll of seed from the gin breast is not removed between bales, some seed from a given bale are held in the roll and mixed with the seed of the second bale following it. In trials made by Ballard

and Doyle in Texas it was found that a certain amount of seed from a particular bale remained in the auger conveyor after the three following bales had been ginned. Some of this seed was mixed with the seed of the fourth bale. Much of the seed planted is from unselected stock and is inferior. If this is mixed with good seed, it soon lowers the value of the whole lot; or if there is crossing between adjacent fields, similar effects result.

Even if all field and gin mixing is prevented, some deterioration will take place in a variety of cotton in course of time. As has been shown elsewhere, many variant forms appear in fields of cotton from year to year. Some few of these are valuable, but the majority are of an undesirable type. These faulty plants cross with others, making hybrid progenies and, after a time, numerous inferior plants. Unless some breeding work is done in the way of rogueing out these inferior plants when they appear, or in selecting the better type of plants to breed from, the variety will not hold up, or maintain its present status.

Duggar<sup>2</sup> estimates that seed of a good variety of cotton will yield 20 per cent more cotton than mixed, mongrel seed. Figures from almost any experiment station variety test show that this is a conservative estimate.

**Plantation Variety Tests.**—A cotton grower should grow only well-bred cotton of a variety adapted to his land and locality. The surest way for him to determine just what he should grow is to conduct a variety test, one or more, on his land where several of the leading varieties are planted, cultivated, and grown under exactly the same conditions. The soil on which the test is made should be as uniform as is to be found on the plantation, the rows should be of equal length and width, the varieties should be thinned alike and picked and weighed separately, etc.

After a choice of variety is made, the question arises, How can a supply of choice seed of this variety be secured? If he has the time and inclination, the planter may produce it himself on the plantation. He can produce as good seed as can be bought, provided he, or someone employed by him, is willing to give this work the time and energy necessary to develop something worth while. Cotton breeding is, as mentioned by Duggar,<sup>2</sup> the work of a specialist, and no one is likely to succeed unless he is willing to specialize in the work. He must, in addition to having mental traits suited to the work, have considerable energy and be willing

and have the strength to endure considerable physical hardship. Day after day must be spent walking up and down cotton rows with July or August sun beating down upon him.

It is usually much less trouble and more satisfactory for a cotton grower to secure at least a start of good seed of the variety desired from the U. S. Department of Agriculture, from an experiment station that is doing cotton breeding, or from a reputable commercial breeder.

**Community Cotton Improvement.**—In certain sections of the Cotton Belt, notably in North Carolina and Arizona, a movement has been started to have all the cotton growers in certain communities grow the same variety of cotton. Tests are first made to determine the best variety for the section, and then all the growers plant the variety chosen. After the system is under way, some one or certain growers of the community do some breeding work to hold up the variety and insure a supply of good seed each year.

The community system has several good features. A better variety will be grown by at least a part of the growers. With but one variety in a community, cross-pollination in the fields and gin mixing of seed are very largely eliminated. The lint cotton may be marketed more advantageously, since there is a considerable quantity of uniform staple. This may be sold coöperatively.

**Handling Planting Seed.**—It is perhaps not necessary to say that, if cotton seed are to be saved for planting purposes, the cotton must not be picked while it is wet, nor must a large amount of green seed cotton, that is, cotton gathered during the first few weeks of picking, be packed in a cotton house. If more than one kind of cotton is grown on a plantation or a change of varieties is made, great caution must be taken to see that cotton houses, picking sacks, wagons, etc., are thoroughly cleaned. If more than one variety is ginned at a gin, it is not safe to let the seed pass through a screw conveyor. If it is not possible to have belt conveyors, the seed should be allowed to fall on the floor in front of the gin stands and be sacked there. Small lots of seed cotton from breeding plats, that is, lots of 100 to 500 pounds of seed cotton, may be fed into the breast of one gin stand by hand and the seed caught in front of the stand. Smaller lots of seed should be ginned on a small gin such as was described elsewhere in this chapter.

It is better in most instances to sack seed at the gin in even-weight bags, say bags that will hold 100 pounds and that are made from 8-ounce burlap. Heavier or finer-woven fabric may cause some seed to heat. While the seed are green, or during the first few weeks of ginning, it is best to stand the sacks on end over the floor of the warehouse. They should not be tied up or piled on top of one another. After 4 or 5 days the sacks may be tied and stacked. They should be stacked in a dry airy place and in such a way that air can circulate between them.

Some authorities recommend delinting cotton seed that are to be used for planting purposes by passing them through delinting machines such as are used in oil mills. Seed that have been delinted plant somewhat more uniformly and will germinate sooner if there is a scarcity of moisture in the soil. But there are some disadvantages: The delinting makes the seed more expensive; there is usually the possibility of having seed mixed if different varieties are delinted on the same set of machines; and green seed are more apt to heat if delinted. Recently, one of the leading seed companies of the country put in delinting machines at considerable expense, but after one year's trial discarded them. They found that, if green seed that had been delinted were packed in a sack, the seed in the center of the sack might heat even if the sack were lying on the floor by itself.

If seed are ginned closely and then passed through a seed cleaner with screens and fans for removing light or immature seed, and stray locks of cotton, trash etc., very satisfactory planting seed are secured.

**Germination Testing.**—It is usually advisable for a cotton grower to have his planting seed tested for germination before planting. This is especially advisable if the weather the fall before was rainy. The seed may have heated or have been injured in some way unknown to the planter. All of the leading seed companies make a careful test of all the seed they sell.

Prime seed germinate 90 per cent or better. Seed which germinate below 85 per cent are considered below standard, but may be satisfactory for planting if a larger quantity per acre is used. Ordinarily, cotton seed will not germinate satisfactorily under 60 to 90 days after the bolls open.

Cotton seed are more difficult to test than corn seed, oats, or most other agricultural seeds. They cannot be tested satisfactorily between moist blotting papers, in moist sawdust, in sand

etc., kept at room temperature. The temperature must be fairly high and uniform, the seeds must be kept moist but not wet, and they must have air. In greenhouses or in other rooms where these conditions obtain, they may be tested in soil satisfactorily. Cotton seed may be tested in germinators heated by a gas jet or by an oil lamp but with these it is difficult to hold the temperature between the proper limits. Where an electric current is available an electric germinator is preferable.

On account of the difficulties met in testing cotton seed, home testing is not very satisfactory, nor advisable. It is better to send samples of seed to a laboratory that is equipped for the work. The U. S. Department of Agriculture has two or more seed-testing laboratories where seeds will be tested free of charge. Most agricultural colleges are equipped for the work and also some county agents. There are in addition some private laboratories that will make tests for a moderate charge.

When a test is to be made, small samples of seed, say  $\frac{1}{2}$  pint, should be taken from various sacks (preferably with a sampling tube so that seeds may be taken from the central part of the sack), or from various parts of the pile of seed if not sacked, so that a representative sample may be secured. The samples should be numbered and corresponding numbers placed on the sacks from which they were obtained.

*Making the Test.*—The first step in testing samples of seed is to count out a given number of seeds from each sample, say 100 or, better, 200 so that a duplicate test may be made. Each of these hundreds is next thoroughly wetted. This may be done by immersing them in water while they are held in the hand and squeezing and relaxing several times to drive air out of the fuzz on the seeds. The seeds are next spread out in a single layer between the folds of moist outing cloth, or cotton flannel, and placed on a wire tray of the germinator. After the seeds have been in the germinator 2 or 3 days a count should be made and all sprouted seeds removed. If allowed to remain in the germinator they may lift the cloth from other seeds that have not yet germinated and these will not have enough moisture. A second count may be made about the sixth day. Usually this is enough to end the test, but in some cases it is advisable to make a third count.

Water should be kept in the lower part of the germinator so that the air will be very humid. The cloths in the upper part of

the germinator tend to become too wet and must be wrung out. The ones in the lower part have a tendency to become too dry and need sprinkling. The seeds should be well wetted at first, but after that should be kept moist, not wet. The temperature may range from 25 to 30°C. (77 to 90°F.). The optimum temperature is probably about 28°C. or 82°F. In some cases slightly better results are obtained by using a night temperature about 4°C. lower than the day temperature.

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## CHAPTER X

### CHEMISTRY OF THE COTTON PLANT

Many chemical analyses have been made of commercial products coming from the cotton plant, but only a comparatively small number have been made of the plant itself or of its different parts.

**Composition of Mature Plants.**—The relative weight of the different parts of a cotton plant will vary greatly with the season, the richness of the soil, and the variety, and these differences will affect the chemical composition in so far as quantity of different compounds is concerned. Figures given are only averages from a number of determinations and are not accurate for specific cases.

McBryde<sup>6</sup> reports relative weights of different parts of mature, dry cotton plants as follows:

	Grams	Per cent
Roots.....	14.55	8.80
Stems.....	38.26	23.15
Leaves.....	33.48	20.25
Burs.....	23.49	14.21
Seed.....	38.07	23.03
Lint.....	17.45	10.56
Total.....	165.30	100

The leaf weight of the foregoing was taken before the plants had shed many leaves. The plants were grown in South Carolina. In other states farther west the percentage of stalk, roots, and leaves, as compared with seed and lint, is considerably greater. Fraps,<sup>7</sup> of Texas, reports the percentage more than twice as great. In districts where boll weevils are prevalent the vegetative parts of plants are large in proportion to the seed and lint.

Young cotton plants contain a high percentage of water. As they become older the water content gradually becomes less until maturity is reached. Anderson and Ross<sup>6</sup> report the water content of fresh young plants 5 weeks old as being 84.7 per cent; of fresh mature plants, 63.7 per cent; water in air-dried mature plants, 7.4 per cent. White<sup>1</sup> made analyses of the fertilizing constituents of cotton plants of one variety, Cleveland, for four successive years. The land on which the plants were grown was a moderately productive "good cotton soil." It was fertilized with a complete fertilizer containing 70.2 pounds of available phosphoric acid, 18 pounds of potash, and 20.8 pounds of nitrogen.

Table VIII compiled from White's results, shows fertilizing constituents of the above-ground portion of mature plants. It will be noticed that there is close agreement between figures obtained in different years.

TABLE VIII.—FERTILIZING CONSTITUENTS IN ABOVE-GROUND PORTION OF MATURE COTTON PLANTS  
(Dry Matter)

Year	Per cent ash	Per cent nitrogen	Composition of ash				
			Per cent phosphorus	Per cent sulphur	Per cent potassium	Per cent calcium	Per cent magnesium
1910	6.15	1.56	3.77	1.70	11.80	13.21	5.25
1911	6.85	1.43	3.10	1.41	11.47	10.82	4.80
1912	7.10	1.50	3.62	1.61	9.41	10.04	4.10
1913	7.25	1.54	2.66	1.55	11.19	11.61	3.99
Average	6.83	1.50	3.28	1.56	10.96	11.42	4.53

Table IX, compiled from results published by different experiment stations, shows fertilizing constituents in entire mature cotton plants grown in different states. These results are figured on a different basis from the ones given by White in Table VIII, and so are not exactly comparable.

TABLE IX.—FERTILIZING CONSTITUENTS OF MATURE COTTON PLANTS

Station	Per cent ash	Per cent nitrogen	Per cent phosphoric acid	Per cent potash	Per cent lime
Alabama.....	6.07	1.56	0.55	1.26	1.65
South Carolina.....	6.27	1.58	0.47	1.43	1.53
North Carolina Department of Agriculture.....	7.28	1.31	0.47	1.34	0.76
Texas.....	.....	1.71	0.45	1.50	2.07

Table X, from McBryde,<sup>8</sup> shows a proximate analysis of an entire mature plant grown in South Carolina.

TABLE X.—PROXIMATE ANALYSIS OF MATURE COTTON PLANT

Per cent water	Per cent ash	Per cent protein	Per cent fiber	Per cent nitrogen-free extract	Per cent fats
7.36	5.81	9.13	30.94	42.84	3.92

From Tables VIII and IX some idea may be obtained of the draft that cotton plants make on the fertility of the soil. This draft is not in direct proportion to the size of the crop. It is greater, comparatively, for small yields and smaller for large ones. Fraps<sup>7</sup> showed that, if a large amount of potash is present in the soil, an excess may be taken up by plants. Possibly the same principle may hold, to some extent, for other nutrients.

Probably a better idea of the drain cotton crops make on the soil can be obtained by considering the pounds of fertilizing constituents found in the lint and seed obtained from an acre of good cotton. In Table XI, compiled from McBryde,<sup>8</sup> the fertilizing constituents in corn, oat, and cotton crops are shown in form for comparison.

TABLE XI.—FERTILIZING CONSTITUENTS IN THE PRODUCTS OF AN ACRE OF  
CORN, OATS, AND COTTON  
(Figures Show Pounds per Acre)

	300 pounds lint cotton	30 bushels oats	20 bushels corn	300 pounds lint and 654 pounds seed	30 bushels oats and 1,515 pounds straw	20 bushels corn and 1,634 pounds stover
Nitrogen.....	0.72	17.50	16.50	20.80	26.50	29.80
Phosphoric acid ( $P_2O_5$ )	0.18	6.00	6.75	6.84	9.00	9.50
Potash ( $K_2O$ ).....	2.22	5.25	5.30	9.85	36.00	30.40
Soda ( $Na_2O$ ).....	0.08	0.15	0.18	0.20	1.65	1.92
Lime ( $CaO$ ).....	0.46	0.75	.....	1.68	5.25	7.93
Magnesia ( $MgO$ ).....	0.41	2.25	2.50	3.67	5.25	8.25
Sulphurous acid ( $SO_3$ ).....	0.26	0.45	0.18	1.10	2.70	.....
Insoluble matter.....	0.08	9.00	0.12	0.23	27.00	23.40

The cotton yield used in the preceding table, 954 pounds seed cotton per acre, is above the average for the Cotton Belt, but it is only a fair crop for well-cultivated cotton on good land. The lint percentage used is a little low for short-staple cotton, but high for long-staple; therefore it averages well. Average crops for the South are about 30 bushels of oats per acre and 20 bushels of corn per acre. It will be observed that the fertility removed from the soil when only the lint is taken away is very little—only about 3 pounds. This drain is very much less than that made by oats and corn (see columns 2 and 3 in Table XI), when only the grain is removed. At present, however, cotton seed is removed also and is rarely returned in manures. Oat straw, as a rule, is likewise taken from the land but corn stover is usually left. The figures, then, in columns 3, 4, and 5 are best for comparison. These indicate that the cotton crop takes more nutrients from the soil than does the grain of a corn crop, but considerably less than does the whole crop of corn or oats.

**Composition of Different Parts of the Cotton Plant.**—Since the different parts of cotton plants differ greatly in composition, and since some parts are used for one purpose and some for another, it is of value to know the definite composition of each part.

Table XII compiled from Anderson and Ross,<sup>6</sup> shows the complete analysis of different parts of a mature cotton plant.

TABLE XII.—COMPLETE ANALYSIS OF PARTS OF MATURE COTTON PLANTS  
(Percentage of Constituents in Water-free Material)

	Nitrogen	Phosphoric acid	Potash	Lime	Magnesia	Oxide of iron	Soda	Sulphuric acid	Silica	Ash	Protein	Fiber	Fat	Carbohydrates
Roots.....	0.48	0.26	0.90	0.45	0.44	0.25	0.44	0.14	0.64	3.72	3.00	40.62	2.78	49.88
Stem.....	0.64	0.21	0.85	0.78	0.28	0.21	0.30	0.14	0.16	3.09	4.00	45.31	1.11	46.49
Leaves.....	2.25	0.48	1.09	5.28	0.94	0.43	0.66	1.05	1.70	12.55	14.06	8.71	8.49	56.19
Bolls.....	1.83	0.78	1.60	0.51	0.55	0.15	0.23	0.42	0.21	4.74	11.44	45.21	9.81	29.07
Seed.....	3.54	1.40	1.13	0.32	0.30	0.03	0.28	0.11	0.02	3.65	22.13	11.91	23.05	39.26
Lint.....	0.18	0.09	0.59	0.07	0.14	0.16	0.07	0.09	0.07	1.25	1.12	87.02	0.61	10.00

It will be noticed that the fertilizing constituents of roots and stem are proportionally about the same. The leaves are conspicuously richer. Also, the bolls are comparatively rich in nutrient elements, but this is to be expected, since they contain the seed. The empty burs are moderately rich in potash and phosphoric acid, but low in nitrogen. The lint is low in all fertilizing elements.

The roots, stems, and bolls are all high in fiber, but the leaves are comparatively low. Roots and stems average about the same in carbohydrates and proteins, but the roots contain considerably more fat. The leaves are rich in all the principal foods—proteins, fats, and carbohydrates—and are nutritious feed for stock. Distasteful organic compounds present in small quantities probably account for the fact that they are not relished by animals. The seed, too, contain food elements in large quantities, and, as is well known, serve as excellent feed for cattle and some other kinds of livestock. Cotton lint is often spoken of as being pure cellulose, but an examination of Table XII will show that it contains several other materials in considerable quantity. It is lower in fertilizer and food elements than all the other main parts of the plant, but it ranks highest in fiber.

The water content of cotton fibers, according to Bowman,<sup>9</sup> varies with the season, ranging from 1 to about 4 per cent in the new crop, and less as the season advances. Above 2 per cent is excessive even in a new crop, and when more than this amount is present, it is likely due to a wet season and the cotton's being

packed before drying, or to the addition of water artificially. McBryde<sup>8</sup> found that if samples of apparently dry cotton were heated to 212°F., they lost from 5 to 7 per cent in weight, but if put back in the room from which they had been taken, they gradually regained all the weight they had lost. This was the so-called "water of hydration."

**Composition of Plants at Different Stages of Growth.**—The composition of cotton plants varies considerably at different stages of growth. White,<sup>1</sup> of Georgia, made analyses of plants in four different stages of development—first form, first bloom, first open boll, and mature plant—for four successive years. He used but one variety, Cleveland Big Boll, and grew plants on good cotton land near Athens, Ga. Before planting, 634 pounds of a mixed fertilizer, consisting of 468 pounds of acid phosphate, 36 pounds of muriate of potash, and 130 pounds of nitrate of soda, were applied in the drill. First forms appeared 34 to 40 days after the seed sprouted; blooms, 24 to 32 days later; open bolls, 57 or 58 days after blooms; and the plants were mature in 90 to 100 days after open bolls appeared.

Tables XIII and XIV show results from analyses made by White in 1910. Figures for other years were very similar.

TABLE XIII.—WEIGHT AND COMPOSITION OF PLANTS AT DIFFERENT STAGES OF GROWTH

*Average Weight of Plants*

(Dry matter weights; only above-ground parts used)

	GRAMS
First form . . . . .	20.83
First bloom . . . . .	48.65
First open boll . . . . .	82.43
Mature plant . . . . .	172.35

*Percentage of Nitrogen in Dry Matter*

PER CENT

First form . . . . .	4.27
First bloom . . . . .	3.60
First open boll . . . . .	2.67
Mature plant . . . . .	1.56

*Percentage of Ash in Dry Matter*

PER CENT

First form . . . . .	13.35
First bloom . . . . .	14.25
First open boll . . . . .	11.38
Mature plant . . . . .	6.15

TABLE XIV.—CHEMICAL COMPOSITION OF THE ASH

	First form, per cent	First bloom, per cent	First open boll, per cent	Mature plant, per cent
Phosphorus.....	5.35	4.28	4.03	3.77
Sulphur.....	2.86	2.16	1.70	1.70
Potassium.....	16.07	12.40	10.20	11.80
Calcium.....	20.00	15.05	12.24	13.21
Magnesium.....	7.86	5.40	5.20	5.25

From Tables XIII and XIV it will be observed that cotton plants make a large gain in weight as they pass from the first-form stage to maturity, and that the percentage of important minerals decreases gradually. Table XV shows that the total mineral weight increases greatly as the plant increases in size.

TABLE XV.—QUANTITATIVE COMPOSITION OF A SINGLE PLANT

	First form, grams	First bloom, grams	First open boll, grams	Mature plant. grams
Dry matter.....	20.83	48.65	82.43	172.35
Ash.....	2.78	6.93	9.38	10.60
Nitrogen.....	0.89	1.75	2.20	2.69
Phosphorus.....	0.15	0.30	0.38	0.40
Sulphur.....	0.08	0.15	0.16	0.18
Potassium.....	0.45	0.87	0.96	1.25
Calcium.....	0.55	1.05	1.15	1.40
Magnesium.....	0.22	0.38	0.49	0.56

TABLE XVI.—PERCENTAGE OF MINERALS TAKEN UP DURING DIFFERENT LIFE PERIODS

	To first form	First form to first bloom	First bloom to first open boll	First open boll to mature plant
Nitrogen.....	34	32	18	16
Phosphorus.....	37	40	18	5
Sulphur.....	43	32	10	15
Potassium.....	35	28	13	14
Calcium.....	33	41	10	16
Magnesium.....	38	31	20	11

From the analyses made during the 4 year's study, White<sup>1</sup> calculated the percentage of mineral nutrients the cotton plant takes up during each of the four periods mentioned above.

From the foregoing and from other data White estimates that, under conditions similar to the ones under which his plants were grown, a cotton plant takes up approximately one-third of its total mineral nutrients during the first period of 30 days; a second third is taken up the second period of 30 days terminating with the formation of the first bloom; by the end of the third period, or by the opening of the first boll, 85 to 90 per cent has been taken. This leaves only 10 to 15 per cent to be added during the maturing period of 90 to 100 days. Most of the total dry matter of the plant, however, is produced during the last period. According to White's figures, approximately one-eighth is produced the first period, one-eighth the second, one-fourth the third, and one-half the last, or maturing, period.

**Relative Composition of Cotton Plants as Affected by Fertilizers.**—It has been demonstrated often that an application of commercial fertilizers will increase cotton yields and produce larger plants. White,<sup>3</sup> in his experiments in Georgia, found that, on the average, a mature plant receiving a moderately heavy application of complete fertilizer contained 155.2 grams of dry matter; one receiving no phosphate, 135.5 grams; one receiving one-half the standard amount of phosphorus, 137.4 grams. He found also that a mature plant receiving the complete fertilizer contained 6.85 per cent ash (on dry-matter basis); one receiving no phosphorus, 6.10 per cent; one receiving one-half the quantity of phosphorus, 5.85 per cent. The last figures are not according to expectation.

The relative amount of nitrogen, potash, and phosphoric acid in plants does not seem to be influenced greatly by fertilizers applied to the soil; this is especially true if the land is moderately rich already. White,<sup>3</sup> as a result of his rather extensive experiments extending over 2 years, was unable to see any definite relation. He concludes:

The obvious indication of these results, as compared with those yielded by the application of the standard fertilizer, is that substantial diminution in amount of either of the principal ingredients of the plant's food—phosphorus, calcium, potassium, or nitrogen—involves (1) substantial reduction in the weight (dry matter) of the plant in its entirety and in the several periods of growth, particularly after setting

of the form; and (2) increase in time period from form to bloom, from bloom to open boll, and in the maturing of the plant. The proportion of ash to dry matter at any stage of growth or relative amounts of nitrogen and mineral ingredients do not appear to be seriously affected by the amount of the food supply. This would seem to indicate the important fact of the absence of a power in the plant to store food in any particular period of growth beyond the needs of the plant for the period.

Anderson,<sup>6</sup> in Alabama, secured results similar to White's. The nitrogen and phosphate fertilizers appeared to give no consistent increase of those elements in the plants, but the potash appeared to be an exception. Its use in fertilizers gave an increase in the plants regularly. Potash also gave an increase in White's experiments, but was used in but two tests. Table XVII, from Anderson's work, shows the composition of plants grown on rich garden soil, and on less fertile field soil with various fertilizers applied to each. (The amount of fertilizer used per acre is not given. The seed cotton weights given in Table XVII are the yields from plats 10 feet square.) The effect of the potash fertilizer is more marked on the poorer soil.

TABLE XVII.—EFFECT OF FERTILIZERS ON THE COMPOSITION OF COTTON PLANTS

Fertilizers used	On field soil				On rich garden soil			
	Per cent potash	Per cent phosphoric acid	Per cent nitrogen	Ounces seed cotton	Per cent potash	Per cent phosphoric acid	Per cent nitrogen	Ounces seed cotton
None.....	1.256	0.788	1.883	9.29	2.538	0.758	2.352	130.83
Nitrate soda and kainit.....	2.123	0.345	1.969	30.00	2.026	0.741	2.436	120.00
Nitrate soda and phosphoric acid.....	1.051	0.537	1.883	23.21	1.494	0.688	2.064	96.25
Kainit and phosphoric acid.....	2.119	0.488	1.841	29.17	2.751	0.900	2.442	132.86
Nitrate soda, kainit, and phosphoric acid	2.562	0.557	1.833	37.50	3.054	0.696	2.339	145.34
None.....	.....	.....	.....	12.50	2.683	0.724	2.273	141.25

Results secured by White,<sup>3</sup> Table XVIII, indicate that the fertilizer used may have considerable effect on the storage of fat in the seed. Lack of phosphorus appears to have the most influence as a deterrent.

TABLE XVIII.—EFFECT OF FERTILIZERS ON STORAGE OF FAT IN COTTON SEED

	Average amount of seed, grams	Average amount of kernel, grams	Per cent kernel	Per cent fat in kernel
<b>1911</b>				
Standard fertilizer.....	0.146	0.066	45.5	42.8
No phosphate.....	0.118	0.052	44.2	36.6
One-half standard phosphate	0.130	0.058	44.8	40.2
No potassium.....	0.120	0.059	45.0	42.0
One-half standard potassium	0.125	0.056	44.9	41.8
No nitrogen.....	0.115	0.050	43.8	39.8
One-half standard nitrogen...	0.125	0.056	44.6	40.1
<b>1912</b>				
Standard fertilizer.....	0.155	0.071	45.8	38.2
No phosphate.....	0.131	0.059	45.0	31.5
One-half standard phosphate	0.145	0.065	44.6	36.5
No potassium.....	0.135	0.061	45.5	38.3
One-half standard potassium	0.140	0.062	44.2	38.0
No nitrogen.....	0.135	0.060	44.8	35.6
One-half standard nitrogen...	0.142	0.064	45.1	37.5

**Effect of Soils on Composition of Cotton Plants.**—It is well known that the character of the soil on which plants are grown determines largely the amount of growth they make and their yields. The effect that various soils have on the relative amount of various chemical compounds in the plants is not so well known. In fact, comparatively little work has been done by investigators on this particular problem. Anderson<sup>6</sup> analyzed some plants grown on rich garden soil and some grown on field soil of fair fertility, but low in organic matter. The garden-soil plants, as is shown by Table XVII, were much richer in potash, phosphoric acid, and nitrogen. Fraps<sup>7</sup> analyzed plants from seven different regions in Texas. A wide variation in composition was obtained, but much of this was probably due to climatic differences. No definite relation to different soil types was established. White<sup>8</sup> analyzed plants grown in different parts of Georgia, but found no wide divergence in composition.

Cotton grown on rich land has lower lint percentage than that grown on poor land, on account of the better-developed seed. The larger, or more perfect, seed contain a slightly higher per-

centage of oil. Oil mills pay \$5 more a ton for seed grown in the Mississippi Delta than for seed grown in the hill section of the state. However, the Delta-grown seed contain more oil mainly because the long-staple varieties are grown there. Most of the long-staple varieties have small seed comparatively rich in oil.

**Difference in Composition of Different Varieties.**—Cotton varieties differ considerably in yields of lint and seed and in lint percentage. This makes some difference in the organic composition of plants, but there seems to be but little difference in the relative percentage of the fertilizer constituents contained. White<sup>3</sup> analyzed varieties in a variety test in Georgia, but found only slight differences in chemical elements. Rast, of Georgia, and Brown, of Mississippi, found that seed of different varieties differ greatly in oil content, the difference being as much as 10 gallons per ton, in some instances, for different varieties grown in the same field.

**Other Organic Compounds in Cotton Plants.**—Numerous organic compounds are found in small quantities in cotton plants. Among these may be mentioned Gossypol, which, according to Withers and Carruth,<sup>2</sup> is the toxic substance in cotton seed meal, and which is present in the secretion of internal glands widely distributed over cotton plants; quercimeritrin and isoquercitrin isolated from petals by Viehoever, Chernoff, and Johns<sup>10</sup>; quer-cimeritrin in leaves; an ethereal oil distilled in small quantities from seedling or squaring plants by Viehoever and others.<sup>10</sup> This oil has the property of attracting boll weevils, and it is possible that it is to them a guide to the plants. There is sugar in the nectaries of flowers and leaves, and other compounds are found in the plants in small quantities, but it does not fall within the province of this work to discuss these.

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## CHAPTER XI

### FERTILIZERS, MANURES, AND ROTATIONS FOR COTTON

Cotton is grown on many fields year after year. As it is a clean-culture crop, there is not much chance for an accumulation of organic matter in the soil; and since the lands are bare during the winter, the period of heaviest rainfall, they are subject to much erosion and leaching. Bacterial action in the soil is active during most of the year. This soon destroys the organic matter that is added or that was present in the fresh soil. As a result of these influences, the lands of the Cotton Belt are, for the most part, low in productivity. Nearly all are low in humus and nitrogen; many have insufficient phosphorus; and some have but little potassium.

Commercial fertilizers are being used considerably on cotton lands, but often they are not applied judiciously. Expensive nitrogenous fertilizers are bought when legumes should be grown; complete fertilizers are frequently used where but one or two constituents are needed. Cotton planters must learn to handle their lands so as to increase the supply of nitrogen and organic matter in the soil; they must learn just what elements are needed, and the most economical sourcee from which to purchase; and they must learn how to prevent loss of nutrients already in the soil by leaching and erosion.

**History of Cotton Fertilization.**—Cotton growers in America have long known the value of stable manures, cotton seed, and clovers as fertilizers, but these were not used extensively until comparatively recently. Formerly, rich, new lands were cheap and labor was cheap and abundant. It was less difficult to acquire and clear fresh lands than to fertilize or build up "worn-out" ones. As a consequence, lands were robbed of their plant nutrients until worn out; then new lands were taken up. The animal manures produced were of little consequence, because not many animals were kept—very few besides the mules and horses used in cultivating the cotton - and since the animals that were kept were allowed to graze in pastures a large part of

the time, manures did not accumulate. Cotton seed was sometimes scattered broadcast over the land and then plowed under. Often it was piled in heaps and left exposed to the weather for several months to rot; then it was scattered.

According to White,<sup>1</sup> few fertilizers were used on cotton prior to 1860. The natural richness of the soil was depended on, and "the virgin soil skimmed." Peruvian guano was introduced into the United States about 1840 and first tried on cotton by David Dickson of Hancock County, Georgia, in 1846. This was probably the first use in the United States of a concentrated fertilizer on cotton. When first tried by Dickson, guano gave surprisingly good results. Other planters began using it with splendid results at first, but later results were not so satisfactory in many instances, on account of the poverty of the soil and the poor cultural practices followed.

Following Liebig's discovery of the value of chemical fertilizers as nutrients for plants, the opening of potash salt beds in Germany, and the discovery of phosphate deposits in Tennessee, Florida, and South Carolina, came the use of artificial manures on a commercial scale. Cotton growers began to use them extensively just after the Civil War (1861 to 1865). The war took their cheap labor from them. No new lands could be cleared, but there was a heavy demand for cotton at good prices. The worn-out lands would not produce well without some aid. Commercial fertilizers met the need exactly. They could be bought and applied without much trouble, and they gave good returns. Their use soon became widespread in the older states of the Cotton Belt. Unfortunately, many growers began to expect too much from the fertilizers. They allowed the soil to become low in organic matter from failure to use proper rotations, and neglected seed-bed preparation and culture, expecting the fertilizers used to make a crop in spite of these handicaps. The failures naturally resulting caused many farmers to consider commercial fertilizers positive evils. They were frequently denounced in public meetings, and some efforts were even made to secure legislative measures to prohibit their sale. Later, better information was distributed and the proper use of fertilizers learned. The use at present is confined principally to states east of the Mississippi River.

**Soil Elements Removed by Cotton.**—Soils in cotton-growing districts are usually poor, but this is not due to the drain that

cotton plants make on the soil. An examination of Table XII and other tables in Chap. X, and Table XIX below will convince one that the draft is comparatively light.

TABLE XIX.—WEIGHT OF PLANTS AND PLANT NUTRIENTS IN PLANTS WHICH PRODUCE A BALE OF COTTON

Part	Per cent of weight	Weight in pounds	Pounds nitrogen	Pounds phosphoric acid	Pounds potash
Root.....	8.8	417	2.00	1.08	3.75
Stems.....	23.15	1,096	7.01	2.30	9.33
Leaves.....	20.25	959	21.58	4.60	10.45
Burs.....	14.21	673	5.52	3.23	20.79
Seed.....	23.03	1,090	38.58	15.26	12.32
Lint.....	10.56	500	0.90	0.45	2.95
Total.....	100.00	4,735	75.59	26.92	59.59

All of the cotton plant is returned to the soil except the seed and the lint. The fertilizer constituents in the seeds are returned in part in manures from animals fed cotton seed meal and in cotton seed fertilizers. The fertilizers in a 500-pound bale of lint weigh less than 5 pounds, and more than half of this is potash, a constituent that is plentiful in most soils.

**Maintenance of Soil Productivity.**—With proper handling, soils may retain their richness and continue to produce well indefinitely. Fields in parts of Europe that have been in cultivation hundreds of years are today producing better than they were a hundred years ago. Fields in China that have been cultivated for 4,000 years are still producing well.

Elements that are scarce in the soil naturally must be supplied in the form of manures or artificial fertilizers. Elements present in the soil may be rendered more available by the introduction of organic matter.

It is not profitable to crop poor land. If land is not productive, it should be made so as soon as possible. After it is built up, the land should be so managed that valuable elements are not lost in excessive amounts by leaching and erosion.

**Response Cotton Makes to Fertilizers.**—Cotton plants respond promptly and liberally to proper fertilizers, whether they be barn manures, legumes in the form of green manures, or chemical

fertilizers. Five loads of stable manure per acre or a crop of cowpeas turned under may double yields on poor soils. Even a light application of commercial fertilizers has an effect and is profitable if the fertilizers are judiciously applied. The fact that it is so sensitive to fertilizers leads to the use of the cotton plant as a test plant in soil-fertility work. Fertilizers not only increase growth and fruitfulness, but in some cases hasten maturity and shorten the entire life period.

**Chemical Fertilizers.**—The chief function of manures is to furnish plants with nitrogen, phosphoric acid, and potash. Natural or barn manures furnish these essential elements, but not in the best proportion. If they are used in quantity sufficient to supply needed phosphoric acid, the nitrogen may be in excess—so much so that the cotton plants become very large, but fail to fruit well. Natural manures are very valuable in that they increase the supply of vegetable matter in the soil and improve its mechanical condition. Natural constituents already present are made more available. Combined with sufficient phosphoric acid and potash (if needed in the particular soil), barn manure makes an ideal fertilizer. Unfortunately, the supply of natural manure is very limited in the cotton states, and chief dependence must be placed on artificial or chemical fertilizers. Many experiments have been carried on during the last 30 years to determine the value of the three important chemical fertilizers as manures for cotton. Much information of practical value has been obtained as to the amount of the different constituents to use on various soils, and where or in what form the different constituents can be obtained most economically.

**Phosphatic Fertilizers.**—The phosphate fertilizers are in several different forms—acid phosphate, raw rock phosphate, ground bones, basic slag, etc.

**Raw Rock Phosphate.**—This material, as the name implies, consists of the untreated phosphatic rock, which is dug from the ground. The greater part of this rock comes from the bones of millions of animals that lived ages ago. The rock is finely ground before being put on the market, and is sometimes designated as "floats." At present, rock phosphate is obtained in commercial quantities from beds in South Carolina, Tennessee, and Florida. There are large undeveloped deposits in Idaho, Wyoming, and Montana. Rock phosphate, although containing about 30 per cent phosphoric acid, is objectionable as a fertilizer for

cotton as the phosphoric acid is in an insoluble form and is not readily available. When used on soil containing much organic matter, or along with a crop of green manure turned under, it may give fair results. Most experiments show acid phosphate to be a better fertilizer for cotton. Being less soluble than acid phosphate, rock phosphate remains in the soil longer and the residual effect is probably greater.

*Acid Phosphate.*—Acid phosphate is made by treating rock phosphate with an equal weight of sulphuric acid. The resulting composition contains, as a rule, 12 to 16 per cent phosphoric acid in soluble form. In this form it is readily available to plants, and when used as a fertilizer for cotton gives quick results.

*Basic Slag and Other Phosphates.*—In addition to the sources of phosphoric acid discussed above, there are several others of lesser importance. Among the number may be mentioned basic slag, a by-product in the manufacture of steel from iron ores high in phosphorus. It is produced and used in Europe chiefly. When used as a fertilizer for cotton, it gives fair results, being better than rock phosphate but not so profitable as acid phosphate. According to Voorhees,<sup>3</sup> it contains 15 to 19 per cent phosphoric acid.

Guanos rich in phosphoric acid were formerly used extensively in fertilizing cotton and gave excellent results. Only an occasional shipment from islands in the Pacific or Atlantic oceans is received at present.

Raw bone, bone tankage, bone black, bone ash, dried ground fish, and several manufactured phosphates are also sources of phosphoric acid, but these are not used extensively in fertilizing cotton.

*Need for Phosphatic Fertilizers.*—Practically all the cotton lands east of the Mississippi River, except the black prairie lands of Alabama and Mississippi and the Yazoo-Mississippi Delta lands, are low in available phosphoric acid. West of the Mississippi most of the sandy land, and much of the rolling clay land as well, is improved by an application of a phosphatic fertilizer. The black Houston clay soils of Texas are similar to the black prairie soils of Alabama and Mississippi. On account of the low content of phosphatic constituents in the mass of the soils of the cotton states, it will probably always be desirable to supply these elements artificially.

*Amount of Phosphoric Acid to Apply.*—The most profitable amount of phosphoric acid to use varies in different regions, depending on the natural condition of the soil, its previous handling, etc. Considerably more is used in eastern states than in western, with apparently more profitable results. In South Carolina, increasing the application up to 600 pounds may give increased yields, but frequently profitable returns are not secured if more than 300 pounds are used. In Texas, the maximum amount is about 200 pounds. In many regions not enough experiments have been made to determine just how much phosphoric acid may be used on cotton with profit. The South Carolina Experiment Station<sup>4</sup> secured a gain of nearly 200 pounds of seed cotton per year for 13 years in a test in which 600 pounds of 8 per cent phosphoric acid was used alone. A fertilizer consisting of 600 pounds of 16 per cent acid phosphate, 3 per cent ammonia, and 3 per cent muriate of potash gave an increase of 748 pounds of seed cotton over the average of the checks. Ames,<sup>5</sup> in the brown-loam section of North Mississippi, secured a gain of 399 pounds of seed cotton from the use of 200 pounds of 16 per cent acid phosphate. Ferris,<sup>6</sup> on the sandy coastal plain soils of South Mississippi, secured as a 6-year average a gain of 345 pounds of seed cotton from an application of 100 pounds of 16 per cent acid phosphate. An average gain of 409 pounds resulted each year from using 200 pounds for 2 years. Fraps,<sup>7</sup> in 151 fertilizer experiments in Texas, secured a gain from the use of phosphoric acid in 74 per cent of his experiments. The average gain, for the experiments which gave gain, was 113 pounds of seed cotton from an application of 150 pounds of acid phosphate.

The margin of profit from the use of phosphate fertilizers is governed not only by the increase in yields but by the market price of the fertilizers and the value of cotton seed and lint. If 100 pounds of 16 per cent acid phosphate gives a gain of 100 pounds of seed cotton, it is profitable and should be used. When used with nitrogenous or potassic fertilizers or with both, greater gains may be secured. Some idea in regard to whether or not it would be profitable to use a phosphate—or any other fertilizer in any particular region—may be obtained from Table XX, which gives recommendations made by agronomists in the several cotton-growing states.

TABLE XX.—FERTILIZERS RECOMMENDED FOR COTTON IN THE COTTON-GROWING STATES

Agronomists and state	Region	Application
T. B. Hutcheson, Virginia	Southern part of state	Liberal application of a fertilizer carrying 10 % phosphoric acid, 4 to 6 % potash. Apply nitrogen to other crops in rotation.
C. B. Williams, North Carolina.	Sandy and sandy-loam soils of coastal plain	500 to 800 lb. of a mixture carrying 6 to 7 % phosphoric acid, 4 to 6 % nitrogen, and 2 to 3 % potash.
	Piedmont and mountain soils	600 to 800 lb. of a mixture containing 10 to 12 % phosphoric acid and 2 to 3 % nitrogen.
C. P. Blackwell, South Carolina.	Sandy soil of coastal plain	400 to 600 lb. of a fertilizer analyzing 6 to 8 % phosphoric acid, 4 to 6 % ammonia, and 3 % potash.
	Sandy-loam soil of coastal plain	400 to 600 lb. of a fertilizer analyzing 7 to 8 % phosphoric acid, 4 to 5 % ammonia, and 2 to 3 % potash.
	Heavier soils of Piedmont section	400 to 600 lb. of a fertilizer analyzing 8 to 10 % phosphoric acid and 4 to 6 % ammonia. No potash.
R. R. Childs, Georgia.....	For sandy soils in southern part of state	200 to 600 lb. of a 10-3-4 or a 10-3-3 fertilizer.
	For northern part of state where clay soils predominate	200 to 600 lb. of a 10-2-3 or a 10-3-3 fertilizer.
M. J. Funchess, Alabama.....	.....	200 to 400 lb. acid phosphate, 100 to 200 lb. nitrate of soda, and 100 to 200 lb. kainit.
J. R. Ricks, Mississippi....	For Yazoo-Mississippi Delta and Northeast Prairie	100 to 250 lb. nitrate of soda or its equivalent in nitrogen content.
	For sandy soils in southern part of state	200 to 300 lb. acid phosphate, and 200 lb. cotton seed meal or its equivalent in nitrogen content.
	For brown-loam soils	200 to 300 lb. acid phosphate and 100 lb. nitrate of soda.
	For all lands in the state on which cotton rusts	100 to 200 lb. kainit.

TABLE XX.—FERTILIZERS RECOMMENDED FOR COTTON IN THE COTTON-GROWING STATES (*Continued*)

Agronomists and state	Region	Application
A. F. Kidder, Louisiana	For sandy lands and others low in organic matter	24 to 32 lb. phosphoric acid in acid phosphate, 12 to 15 lb. nitrogen in cotton seed meal, and 8 to 10 lb. nitrogen in nitrate soda or sulphate ammonia.
	For lands of medium fertility	16 to 24 lb. phosphoric acid in acid phosphate and 8 to 10 lb. nitrogen in cotton seed meal.
W. H. Sacks, Arkansas	For sand and sandy-loam soils, medium fertile	300 to 400 lb. of an 8-10-2-4-2-4 fertilizer.
	For silt loams and sandy clays, medium fertile	300 to 500 lb. of an 8-9-2-3-2-3 fertilizer.
	For clay loam and clay uplands	300 to 500 lb. of an 8-10-2-3-0 fertilizer.
	For delta or bottom lands, fairly fertile	200 to 300 lb. of an 16-0-0 fertilizer.
Glenn Briggs, Oklahoma	.....	But few fertilizer experiments have been conducted. Acid phosphate appears to be the only fertilizer that is profitable.
A. H. Leidigh, Texas	Sandy soils of low fertility in eastern part of state	100 to 400 lb. of a half-and-half mixture of cotton seed meal and acid phosphate.
	Sandy soils of medium fertility in eastern part of state	100 to 400 lb. of a mixture consisting of two parts acid phosphate and one part of cotton seed meal.
W. E. Bryan, Arizona	.....	No fertilizers are recommended.
B. A. Madison, California	.....	No fertilizers used.

*Time and Method of Applying Phosphate Fertilizers.*—Since all forms of phosphate fertilizers remain in the soil well, there is no object to be gained by applying them after the planting. Before planting they can be put in more economically and in better condition. They may be distributed by hand in the furrow, or with a fertilizer distributor and then bedded on; or they may be put in beds, already made, with a distributor. The fertilizer should be put down deep enough so that it will not come in direct contact with the seed to be planted later. If a large

quantity of fertilizer is used, it is advisable to run through the bed with a narrow shovel on a single-shovel plow in order to mix the fertilizer with the soil.

**Nitrogenous Fertilizers.**—Nitrogen is a necessary element in the growth of plants. In its pure form, a gas of the air, it is not available to any plants except bacteria. It exists in nature in many different organic and in several inorganic compounds. In a nitrate, an inorganic compound, it is directly available for plants. Other compounds must be changed to this form before the nitrogen contained can be used.

*Fertilizers Which Contain Nitrogen.*—The more important sources of nitrogen for fertilizing cotton are legumes, such as clovers, cowpeas, and soy beans; farm manures; nitrate of soda obtained from extensive beds in Chili, South America (the commercial products containing 15.5 to 16 per cent nitrogen); sulphate of ammonia, obtained principally as a by-product in the manufacture of coke and illuminating gas from coal (containing about 20 per cent nitrogen); calcium nitrate (a manufactured product containing about 12 to 14 per cent nitrogen); calcium cyanamid (containing, in the commercial product, about 21 per cent nitrogen); dried blood from large slaughter houses (containing 6 to 14 per cent nitrogen); tankage, dried animal wastes from large slaughtering establishments (containing from 4 to 12 per cent nitrogen); cotton seed meal, the residue left from cotton seed kernels after oil is extracted (containing 6 to 7 per cent nitrogen); cotton seed (containing about 3.5 per cent nitrogen).

*Relative Value of Nitrogenous Fertilizers.*—The value of any of the various nitrogenous fertilizers depends, of course, on the amount of nitrogen contained and its availability. Results obtained by different experimenters have varied to some extent, but, in general, there is not a great amount of difference between fertilizers of the same type, a pound of nitrogen in one being about equivalent to a pound in another. Nitrate of soda, ammonium sulphate, and ammonium nitrate have ranked near together, but calcium cyanamid has given much poorer results, as shown by fertilizer tests. The organic fertilizers, cotton seed meal, cotton seed, peanut meal, velvet bean meal, etc., have ranked only fair as compared with nitrate of soda, but their residual effect is greater. The following tables from the Alabama<sup>8</sup> and Mississippi<sup>9</sup> Experiment Stations throw light on the relative value of nitrogenous fertilizers.

TABLE XXI.—RELATIVE EFFECT OF NITROGEN FROM DIFFERENT SOURCES ON COTTON

(Alabama Agriculture Experiment Station Results, 1921)

Amount, pounds	Fertilizer per acre	Yield of seed cotton, pounds			Average per acre		Per cent of availability
		1917	1918	1920	Yield of seed cotton, pounds	Gains from nitrogenous fertilizer in 1918-1920, pounds	
140	Nitrate of soda .....	823	1,312	809	981	306	100
351	Cotton seed meal .....	825	1,178	758	920	213	94
425	Peanut meal (with hulls) .....	779	1,161	678	873	165	89
754	Velvet bean meal (with hulls) .....	550	1,132	639	774	131	79
	No nitrogen .....		1,070	440			

TABLE XXII.—RESULTS OF A TEST OF VARIOUS NITROGENOUS FERTILIZERS UNDER COTTON\*

(Mississippi Delta Branch Experiment Station, 1921-1925)

Source	Average yield of seed cotton per acre pounds	Gain due to fertilizer, pounds seed cotton	Money value of gain in 1921	Cost of application in 1921	Profit or loss in 1921
Check .....	1,377.5				
Nitrate of soda .....	1,591.1	173.6	\$26.83	\$2.50	\$24.33
Ammonium nitrate .....	1,589.2	211.7	23.32	2.50	20.82
Ammonium sulphate .....	1,616.2	238.7	27.84	2.50	25.34
Check .....	1,377.5				
Cyanamid .....	1,488.9	111.4	2.21	2.50	0.29
Cotton seed meal .....	1,579.1	201.6	17.79	3.75	14.04
Cotton seed meal and nitrate of soda .....	1,615.5	238.0	17.19	3.13	14.06
Check .....	1,377.5				

\* All materials were applied at such a rate as to add 15 pounds of nitrogen per acre in 1921 and 1922; 22.5 pounds in 1923 and 1924; and 30 pounds in 1925. Where cotton seed meal and nitrate of soda were used together, they were used in as 1:1 ratio based on nitrogen content.

Calcium cyanamid must be applied cautiously if used as a side dressing. If it reaches the leaves of young plants or the moist leaves of older ones, it burns the foliage.

Barn manures are valuable as a source of nitrogen. Results following their use are better than the quantity of nitrogen contained would indicate. Clovers, peas, vetches, and other

legumes, where used in proper rotations, constitute the cheapest and best source of nitrogen.

*Amount of Nitrogenous Fertilizers to Use.*—The most satisfactory amount of nitrogenous fertilizer to use varies with the soil and with the season. Ordinarily, it is not advisable to use less than 16 pounds of nitrogen per acre. Increasing the amount of 40 pounds usually increases profits, but the use of more than that amount is uncertain in results. It may be conducive to somewhat larger yields, but the margin of profit is apt to be less. If too much is used, the plants may make too much vegetative growth and fruit poorly. Table XXIII from the Delta Branch Experiment Station<sup>9</sup> gives valuable data on the use of various amounts of nitrate of soda under cotton grown on loam soil in the Mississippi Delta.

TABLE XXIII.—VARIOUS RATES OF APPLICATION OF NITRATE OF SODA

Rate, pounds	Pounds seed cotton per acre	Gain in seed cotton due to fertilizer, pounds	Cost of application	Profit
Check.....	1,464			
50.....	1,511	55	\$1.25	\$ 4.28
100.....	1,578	130	2.50	10.57
150.....	1,677	237	3.75	20.07
Check.....	1,331			
200.....	1,666	329	5.00	28.06
250.....	1,751	407	6.25	34.65
300.....	1,664	313	7.50	23.96
Check.....	1,357			

Value of lint, 30 cents per pound; seed, \$30 per ton.

Ewing,<sup>9</sup> on loam soil in the Mississippi Delta at Scott, secured a gain in yield of 13.6 per cent from the use of 100 pounds of nitrate of soda, and a gain of 16.8 per cent from 100 pounds of nitrate of soda on buckshot soil. One hundred and fifty pounds of nitrate of soda gave a gain of 19.9 per cent on loam soil and 20.6 per cent on buckshot. These data were based on 4 years' work.

*Time to Apply Nitrogenous Fertilizers.*—While results obtained from using nitrogen-bearing fertilizers at different stages

in the growth of the plant vary considerably, owing to soil, and especially seasonal, differences, it is the general opinion of agronomists that nitrate of soda and easily soluble fertilizers should be applied fairly early, either a part before planting and the rest about the time squares appear, or in one application soon after the cotton is thinned and hoed out. If applied before planting, there is danger that some of the fertilizer may be lost by leaching; or, if there are frequent rains early in the season, much of the fertilizer may be used in stimulating grass and weeds to extra growth and the extra cotton plants that are to be taken out. One hundred and forty pound of nitrate of soda applied just after chopping out gave Cauthen<sup>10</sup> 80 pounds more seed cotton per acre than the same amount applied before planting. Nitrate applied when the first squares appeared or when the first blooms showed gave lower yields by 40 or 50 pounds than when it was applied just after chopping out. These figures represent averages from tests running through 6 years. If the nitrate is applied late in the growth of the cotton plant, say after blooming has started, and a period of dry weather ensues, not much of the fertilizer will be absorbed, or, if absorbed, the effect may come too late to help in the production of fruit. Consequently, but little benefit is derived.

Cotton seed meal, cotton seed, and all other organic fertilizers should be applied before planting. It is necessary for them to decay and go through certain chemical changes before the nitrogen contained is available.

**Potassic Fertilizers.**—The use of fertilizers containing potash usually gives less profit with cotton than nitrogenous or phosphatic fertilizers, since most cotton soils are naturally well supplied with potash, and, as cotton stalks are commonly left on the land, the cotton crop removes but a small amount of potash from the soil.

The chief potassic fertilizers used on cotton are kainit (containing about 12 per cent potash), muriate of potash (containing approximately 50 per cent potash), and sulphate of potash (containing about 50 per cent potash). The bulk of these fertilizers comes from extensive salt beds in the region of the Hartz Mountains in northern Germany.

There seems to be little difference in the fertilizing value of the different forms of potash mentioned. A pound of potash in one form has as much effect as a pound in any other. This

being the case, it behooves the grower to use the form which will yield him a pound of potash for the least money.

*Gains Due to the Use of Potassic Fertilizers.*—Some gains from the use of potash have been reported by different experimenters, but, on the whole, gains are rather uncertain when it is used simply as a plant nutrient. Its use is not recommended west of the Mississippi River except on certain sandy-loam soils in Arkansas. It formerly was used in Mississippi and Alabama but very little, except on soil where cotton rusts, but more recently its use has increased considerably. In the eastern states its chief value is as a rust preventive. On thin, run-down, sandy soils it is frequently needed. All of the three forms of potash appear to be equally effective against rust.

*Amount of Potash to Use.*—From 50 to 200 pounds of kainit is recommended for certain regions. As a rust preventive, probably not less than 100 pounds per acre should be used. Larger amounts do not appear to be any more effective.

Potash fertilizers should be applied before planting.

**Lime.**—Lime as a fertilizer for cotton seems to be of little value. Duggar<sup>2</sup> made a number of tests in Alabama, but secured no consistent gains. South Carolina reports no benefit. Lime used in a cotton, corn, oats, and cowpeas rotation at A. and M. College, Mississippi, gave no increase in yields.

Where the land is sour or acid an application of lime may be of some help, but cotton is not much affected by slight acidity of the soil.

**Barn Manures.**—The composition and value of barn manures vary much, depending on the feeds the animals have consumed and the care that has been used in handling the manures. Average barn manure from cities contains per ton, according to Voorhees,<sup>3</sup> 8 to 10 pounds of phosphoric acid, 6 to 8 pounds of potash, and 8 to 10 pounds of nitrogen. Animals fed legume hay will produce manure rich in nitrogen. Manure collected under cover with but little bedding being used is considerably richer than the city manure mentioned above. Trotter, of Mississippi Experiment Station, reporting the composition of mule manure collected under cover and relatively pure, gave available phosphoric acid, 1.1 per cent; nitrogen, 0.82 per cent; and potash, 0.80 per cent.

The secondary value of barn manure is of much importance to poor cotton soils low in organic matter. It improves their

mechanical condition, increases their water-holding capacity, and promotes bacterial action. The Mississippi Experiment Station and a number of other experimenters report larger gains from the use of barn manures than from the use of any other fertilizers.

Although there is abundant evidence that barn manure is a splendid fertilizer for cotton, its scarcity on the farms of the South renders its use a matter of little consequence. Possibly the mention of its valuable qualities will influence some farmer to keep more livestock and produce more manure.

**Green Manures.**—As has been mentioned frequently, most soils of the Cotton Belt could be improved greatly by the addition of a quantity of vegetable matter. Since the supply of barn manure is limited, the only practicable source of vegetable matter is green manures. Green manures fall into two groups—legumes and non-legumes.

The legumes include true clovers, vetches, bur clover, cowpeas, soy beans, and velvet beans. Legumes are valuable in that they increase the supply of nitrogen in the soil, increase organic matter, and serve as a cover crop. The non-legumes used for green manures are rye, barley, wheat, and oats. These will make quicker and greater growth during winter than the legumes, and are better as a winter cover crop; but, considered as a whole, they are not so valuable as the legumes for use as green manures.

Duggar,<sup>2</sup> in Alabama, in 1899, secured a gain of 696 pounds of seed cotton from a green manure crop of cowpeas, and a gain of 536 pounds from a crop of velvet beans. The peas and beans were picked and the vines turned under. Velvet bean plots in which only the stubble was turned under gave a gain of 424 pounds. This is a good gain from the use of the stubble alone. Turning under the stubble is really more profitable than turning under the whole crop. Other southern experiment stations have secured similar results, but the margin of gain is usually not so large as is indicated in the experiments just mentioned.

**Guanos.**—The true guanos are deposits of dung from various species of seafowl, bats, etc. They have been used as fertilizers for centuries, but it was not until near the middle of the nineteenth century that their true value was recognized by the commercial world. The supply, however, was practically exhausted in a few years. Since the amount of guano accumulated each

year is limited, the production at present is a matter of small consequence.

The main supply of guano came from the coast of Peru and adjacent islands. The best of this product contained 12 to 14 per cent nitrogen and 12 to 14 per cent phosphoric acid, and was excellent fertilizer for cotton. It was first used on cotton about 1845. For a few years surprisingly good results followed its use. At present the term is used to a limited extent as a trade name for certain mixed chemical fertilizers, which may or may not contain true guano.

**Composts for Cotton.**—From about 1870 to 1880 or a little later composts for cotton were widely advocated by Farish Furman, of Georgia, and by a few other writers. Their use soon became rather general. The composts were made by piling together in successive layers barn manure, cotton seed, acid phosphate, kainit, and sometimes earth and other fertilizer materials. The compost was moistened and allowed to ferment for a few weeks. Then it was thoroughly mixed and applied in the drill before the planting. Careful experiments made by the Alabama Experiment Station<sup>2</sup> and by other stations have failed to show positive gains from the use of the composted material as compared with the use of equal amounts of the same materials in fresh condition. Composts for cotton are used very little at present by practical growers.

**Cotton Fertilizers Recommended by Agronomists of the Southern States.**—Recommendations for the more important soil belts in the various cotton-growing states are shown in Table XX. These recommendations are rather conservative, and are based on averages from experimental results and various observations of results from practical farming operations. They will serve as a safe guide for planters to follow.

**Best Mode of Applying Fertilizers.**—For all moderate amounts, applying fertilizer in the drill will give better results than broadcasting applications. Williams,<sup>11</sup> of North Carolina, secured 156 pounds more seed cotton per acre from fertilizer applied in the drill than when it was broadcasted. This result was the average of three different tests, all of which gave better returns from the drill application.

Ordinarily, fertilizers are placed about 1 inch below the seed. This practice appears to give better results than does placing

them deeper, as shown by results from North Carolina and Louisiana Experiment Stations.

Dividing the application is of no benefit in the use of any except the easily soluble nitrogen fertilizers, and divided applications of these will not always give better returns than one large application early in the season. Dividing the application makes extra work, and is often not practicable.

**Effect of Fertilizers on Maturity.**—All fertilizers applied judiciously cause a quickening in the growth of cotton plants, a larger plant growth, earlier blooming, the production of more and earlier bolls, and an earlier opening of bolls, thus insuring greater production at the first picking. It is probable, however, that much of the apparent increase in earliness is due to a general increase in productiveness.

Most experimenters have reached the conclusion that nitrogenous fertilizers used in limited amounts or in connection with other nutrients will increase earliness to some extent; but if used alone in large quantities they produce extra vegetative growth and retard fruiting.

Phosphoric acid, if used properly, tends to hasten maturity more than do other fertilizers. Results secured at the Texas Station and reported in *Bulletin 75* are very striking. Plants on the plots fertilized with acid phosphate were 18 inches high when the plants on neighboring plots receiving other fertilizers were half the height and had less than half as many squares. Williams, of North Carolina, secured a gain of from 12 to 35 per cent at the first picking from the use of phosphoric acid. Potash used on sandy land or on land where cotton is inclined to rust will retard maturity in a sense. It will tend to cause the plants to hold their leaves, remain alive, and open their bolls later. This retarding is really not making the plants later, but it is keeping them alive and allowing them to function more normally. A later but much heavier crop is produced.

White, of the Georgia Experiment Station, found that a complete fertilizer advanced the period of boll opening about 10 days on the average. Williams, of North Carolina, reported a gain of 11 per cent at first picking from the use of 1,000 pounds of slaked lime applied at 4-year periods, when used in connection with a complete fertilizer.

**Cumulative Effect of Manures and Fertilizers.**—With the limited amount of commercial fertilizer ordinarily used per acre

the cumulative effect from year to year is very slight. In fact, it most frequently happens that, with the light application of fertilizers and poor cultural practices followed, the land is continually becoming less productive. Where the application is moderately heavy, say 500 pounds or more, the effect the second year, or the accumulative effect, may be considerable. Ordinarily, the effects of nitrogenous fertilizers are not carried over to an appreciable extent. But this may not be the case. At the Mississippi Delta Branch Experiment Station, the effect the second year from 100 pounds of nitrate of soda was sufficient to cause an increase in yield amounting to about 100 pounds seed cotton. The nitrate was applied to cotton the first year. Dry weather ensuing probably retarded its assimilation. Phosphatic and potassic fertilizers are held in the soil longer than nitrogenous. It is well known that the beneficial effects of barn manures extend over 3 or 4 years. Only about half the effect is secured the first year.

White<sup>1</sup> gives the following summary of experimental work:

The cumulative effect of manures in the soil is fairly well evidenced in several cases. Nitrogenous manures increased the yield the second season without additional fertilization (Alabama, Arkansas), but not the third season (Alabama). Phosphatic manures increased the yield, without additional fertilization, the second and third seasons (Alabama). The cumulative effects of heavy applications of a complete fertilizer were manifest the second and third years (Georgia). Floats alone gave a greater increase over no manure the third year after application than in the first or second year (Alabama).

**Fertilizers in Relation to Cotton Diseases.**—Fertilizers are of considerable value in checking the ravages of certain cotton diseases. Potash is almost a specific remedy for black rust. Barn manure or complete fertilizers applied to soil infected with wilt may so stimulate and increase the growth of the cotton plants that they make fair yields before the disease cuts them down. (This applies especially to land not badly infected with wilt.) In general the same principles apply to the use of fertilizers to lessen the damage done by insect pests. Heavy applications of nitrogen, however, sometimes cause very luxuriant growth and heavy development of foliage. The dense shade thus produced is favorable for fungous growth on the bolls and much boll rot results.

**Maintaining Productivity by the Use of Chemical Fertilizers Alone.**—It is a difficult matter to maintain the productivity of cotton soils by the use of chemical fertilizers solely. These supply the common plant nutrients, but do not provide for an increase of vegetable matter. If the land is in good condition to begin with and sufficient fertilizers are used, the vegetative growth of the cotton plants may be sufficient to supply organic matter enough to last for a considerable time.

**Judging Fertilizer Needs by the Appearance of Plants.**—It is not possible to say just what fertilizers are needed on a particular tract of land from the appearance of the plants growing on it, but a good guess may be made. If plants are vigorous in growth and dark green in color, there is doubtless plenty of nitrogen in the soil. On the other hand, if the plants are small, pale, and sickly looking, it does not mean, necessarily, that nitrogen is lacking. Faulty nutrition of any sort, or diseases, may have a similar effect on plants. Premature curling or shedding of leaves may indicate black rust and a need for potash. The safest and by far the best method of determining what fertilizers will be helpful and profitable on any particular field is to conduct a fertilizer test in which various fertilizers are tried under uniform conditions.

**Suggestive Plan for Fertilizer Test.**—Select an acre of land with as uniform and typical soil as is available. Divide this acre into ten equal plats. Plow, plant, thin, and handle these plats alike in every way except in respect to the fertilizer applications. Use fertilizers on the plats as follows:

- Plat 1. No fertilizer.
- Plat 2. Ten pounds of nitrate of soda as a side dressing after chopping out cotton.
- Plat 3. Twenty pounds of 16 per cent acid phosphate in the drill before planting.
- Plat 4. Ten pounds of kainit in drill before planting.
- Plat 5. No fertilizer.
- Plat 6. Twenty pounds of acid phosphate in drill before planting, and 10 pounds of nitrate of soda as a side dressing after chopping out.
- Plat 7. Twenty pounds of acid phosphate and 10 pounds of kainit in drill before planting, and 10 pounds of nitrate of soda as a side dressing after chopping out.
- Plat 8. A ton of barn manure scattered broadcast before bed-  
ding and 20 pounds of acid phosphate in drill before planting.

**Plat 9.** Grow and turn under the previous season a crop of soy beans or cowpeas.

**Plat 10.** No fertilizer.

Stands should be the same on all plats. All fertilizers used should be weighed carefully, and extreme care taken to avoid mistakes when applications are made. All plats must be picked and weighed separately. The average yield from plats receiving no fertilizer will serve as a check with which to compare yield of plats receiving different treatments. One year's testing will be of help to a grower in deciding what fertilizers he should use, but tests running through several years will give more reliable information. It is better to change the location of the plats in different years, and duplicate the series of plats.

**Home-mixed Fertilizers.**—Home-mixed fertilizers are not so well mixed as the factory product, but there are several advantages to be gained from buying the ingredients separately and mixing them in the proportion wanted. The total cost of the fertilizer will not be so great, and it will be much easier to get just the ingredients needed for the land in question. In many instances complete fertilizers are bought when only one or two constituents are needed. Factory-mixed fertilizers are made for several different crops, but are not especially adapted to any particular one. Home-mixed fertilizer may be built up to suit the particular crop.

**Amount of Fertilizers Used by Practical Growers.**—Cotton growers use but little barn manure on cotton. Not much barn manure is saved on the farms, and a considerable part of this is applied to corn and other crops. Green manures in the form of legumes employed in rotations are used on probably 10 per cent of the land normally devoted to cotton.

As has been pointed out, chemical fertilizers are used much more extensively in the eastern states of the cotton belt than in the western, but the use is increasing everywhere (see Table XXIV).

**Profits from the Use of Commercial Fertilizers.**—That there is a profit in the use of chemical fertilizers is evidenced by the fact that their use is increasing. The percentage of profit fluctuates considerably, of course, depending on the price of cotton and the cost of fertilizers, but if they are applied judiciously there will usually be a fair profit. Duggar concluded, from a number of experiments in Alabama, that a ton of mixed

fertilizer when applied to 4 or 5 acres of cotton would make an increase equivalent to a 500-pound bale of cotton and 1,000 pounds of seed. This seems to us to be a fair estimate for regions where a complete fertilizer is needed. The gain is equal to a 100 per cent profit on the investment at present prices of cotton and cotton seed. If but one or two of the essential fertilizer constituents are needed, the margin of profit will be greater.

TABLE XXIV.—FERTILIZERS USED ON COTTON<sup>a</sup>

States	Acres of cotton planted, July 1, thousands		Acres of cotton fertilized, <sup>b</sup> thousands		Total fertilizer used on cotton, <sup>b</sup> tons		Total value of fertilizer used on cotton, thousand dollars	
	1922	1923	1922	1923	1922	1923	1922	1923
Virginia.....	57	83	53	79	10,600	15,208	329	487
North Carolina.....	1,654	1,704	1,571	1,670	322,055	371,575	9,984	11,222
South Carolina.....	1,951	2,049	1,717	1,824	240,380	282,720	7,067	7,775
Georgia.....	3,636	3,927	3,018	3,652	328,962	456,500	9,737	13,604
Florida.....	122	171	98	150	9,800	18,750	260	544
Alabama.....	2,807	3,312	2,189	2,915	229,845	335,225	6,390	10,224
Mississippi.....	3,076	3,353	923	1,475	92,300	140,125	2,723	5,044
Louisiana.....	1,175	1,316	235	500	22,325	47,500	670	1,686
Texas.....	12,241	14,077	245	704	20,825	66,880	656	2,274
Arkansas.....	2,827	3,025	424	938	41,340	86,765	1,282	2,967
Tennessee.....	994	1,193	248	358	24,800	37,590	508	1,071
Missouri.....	201	394	.....	12	.....	1,200	.....	48
Oklahoma.....	3,052	3,357	.....	34	.....	2,550	.....	82
California.....	210 <sup>b</sup>	235 <sup>b</sup>	.....	.....	.....	.....	.....	.....
Arizona.....	105	133	.....	.....	.....	.....	.....	.....
New Mexico.....	18	115	.....	.....	.....	.....	.....	.....
	34,016	38,287	10,721	14,311	1,343,232	1,862,588	39,606	57,028

<sup>a</sup> From "Cotton Facts," 1923.

<sup>b</sup> Indicated totals based upon reports.

Cotton seed meal and nitrate of soda are not included in the report of this state.

Including in California 140,000 acres in 1922 and 157,000 acres in 1923 planted in Lower California (Mexico), but excluded from "Total, above states."

**Fertilizers Used on Cotton in Foreign Countries.**—In the rich Nile Delta of Egypt commercial fertilizers are used but little. Fertilizer tests made by Hughes,<sup>12</sup> in 1908, showed but slight gains from their use. The annual overflow of the Nile brings much nutrient material. All available barnyard manures and some Koufri manure (soil from old village sites) are used. Considerable berseem clover is grown.

Experiment stations in India have shown that nitrogenous fertilizers increase production, and are urging the use of legumes,

green manure crops, and crop rotation. Farmers use a little poudrette, night soil, cattle manure, vegetable waste, wood ashes, etc. Only a small amount of commercial fertilizer is used. With the introduction of better cultural practices will doubtless come more extended use of fertilizers.

Although the soils of China have been cultivated for 4,000 years, they still produce well. The fertility has been maintained, by the use of homemade fertilizers, such as night soil, bone meal, ashes, barnyard manures, soybean meal, talc rock, etc.

Practically no fertilizers are used on cotton in Brazil. Much rich, virgin soil is still available.

**Rotations.**—The use of rotations is advantageous for several reasons: (1) They permit the use of crops that add an extra supply of organic matter to the soil. (2) They allow the use of legume crops, which increase the supply of nitrogen. (3) A change of crops tends to check insect and fungous diseases. (4) Troublesome weeds are held in check more easily. (5) Some crops feed from deeper layers of soil than others. A change may tend to rest some parts, or draw most heavily on fresher parts and give better returns in yields. (6) Not all crops require just the same proportion of mineral nutrients. A change may work to advantage.

*Rotations Alone Will Not Maintain Yields.*—By means of proper rotations the supply of organic matter in the soil can be kept up and the purchase of nitrogenous fertilizers will be unnecessary. But if the soil is lacking in phosphoric acid or potash these must be secured from some outside source, as commercial fertilizers, barn manures, etc., and applied to the soil.

*Good Rotations to Use.*—The rotation most suitable for any particular field or farm is determined largely by the type of farming followed as a main business. If the chief interest is in dairy-ing or in raising stock, and cotton is grown as a secondary crop, rotations that will allow plenty of feed crops should hold first place. If the chief interest is growing cotton, a rotation system that will give cotton crops as often as is possible for good crops to be made will be most satisfactory.

#### THREE-YEAR ROTATION FOR GENERAL FARMING

First year. Corn, with cowpeas at laying-by time, or soybeans in drill at planting.

Second year. Oats, followed by cowpeas after harvesting the oats.

Third year. Cotton, with rye in middles after first picking.

## FOUR-YEAR ROTATION FOR A COTTON FARMER

First year. Cotton, with rye in middles after first picking.  
 Second year. Corn, with cowpeas at laying-by time or soybeans in drill at planting.  
 Third year. Oats, followed by cowpeas after harvesting oats.  
 Fourth year. Cotton, with rye in middles after first picking.

## THREE-YEAR ROTATION FOR A COTTON FARMER

First year. Cotton, with rye in middles after first picking.  
 Second year. Corn, with cowpeas at laying-by time, or soybeans in drill at planting.  
 Third year. Cotton with rye in middles after first picking.

In some cases it may be desirable to grow cotton 3 years in succession with corn and legumes the fourth year. Various combinations can be devised to suit particular conditions.

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## CHAPTER XII

### COTTON SOILS AND CLIMATE

#### SOILS

The Cotton Belt of the United States contains a variety of soils. Cotton is cultivated on most of them, especially where climatic conditions are favorable, but the profits secured vary considerably. Plants on the upland sandy soils, for the most part, yield poorly unless fertilized well. Rich clay soils commonly produce good vegetative growth, but plants do not fruit in proportion. This is especially true if the rainfall is heavy. Bottom lands likewise may produce vegetative growth in excess, unless conditions are very favorable. Fungous diseases are apt to be serious if vegetative growth is excessive. The best and safest lands are medium grades of loam.\*

The total area of the Cotton Belt in the United States is about 300,000,000 acres. In 1920, 35,878,000 acres were in cotton. This was about 12 per cent of the entire area, and about 50 per cent of the acreage in crops. The soils of the belt are such that the acreage in cotton can be increased greatly if the demand for cotton justifies it.

**Chemical Properties of Soils.**—When agricultural chemists first began analyzing soils it was thought that, by determining the quantity of the various essential soil elements present, and by adding fertilizers to make up deficiencies, soils could easily be made productive. A few year's experimenting, revealed that there was no simple relation between the quantity of fertilizer constituents as shown by soil analysis and the yields. A soil might show an abundance of nutrient elements in the chemical analysis, and yet produce poorly. They may be present, but in a form not available to plants, or some contrary factor may inhibit production. It is surprising that an application of a hundred pounds of chemical fertilizer to an acre of land that

\* This discussion of soils is based largely on information contained in various papers and reports from the Bureau of Soils, U. S. Department of Agriculture.

already contains many times the amount of the essential element added in the fertilizer may have so much effect on production. Many problems in connection with the chemistry of soils await solution.

**Physical Structure of Soils.**—The physical structure of soils is a matter of much importance in the growth of plants. Soils may be loose or compact, hard or friable, granulated or non-granulated, and different in many other ways. According to Lyon,<sup>1</sup> granulation is the most important of the favorable structural conditions. It is, in substance, the drawing together of the small soil particles around a suitable nucleus, so that a crumb structure is produced. The small grains cease to function individually, but serve in a larger unit.

Granulation in a heavy soil is instrumental in making the soil looser; this allows the air to circulate more freely, permits the excess water to drain out with little hindrance, and makes it possible for water to respond freely to the capillary pull of the plant roots. Various causes influence or bring about the granulation of soils, among which may be mentioned unequal expansion and contraction of different parts of the soil mass, tillage operations, development of plant roots, the burrowing of animals and insects, the action of decaying organic matter, the effect of wetting and drying, the effect of freezing and thawing, and the flocculation of soil substances induced by an application of lime. The colloidal matter in soils, which acts as a binding agent, has a very important relation to granulation.

Soils well supplied with organic matter have a loose structure; they contain large air spaces, and possess numerous lines of weakness between particles. They expand and contract freely with change of water content; the dried soil contracts so much that large cracks appear in the surface of the ground. These soils are commonly black. As they become older, or the supply of organic matter is decreased, they become heavier, more compact, lighter in color, and less productive.

Soils are said to be in condition of good tilth if they work well and crops grow vigorously on them. Conditions that are most favorable for plant growth are also best for effective plowing and for the development of crumb structure in the soils. On account of the high cohesion and plasticity of heavy soils, the moisture zone for successful plowing is narrow; that is, much of the time it is either too wet or too dry to plow. Their cohesion

causes them to be hard to plow when dry, and when they are plowed, they break up cloddy. The high plasticity causes the soil to puddle badly if plowed too wet.

Soil particles vary in size from stone pebbles to the microscopic particles of clay less than 0.005 millimeter in diameter. They vary in form, ranging from rounded or nearly spherical to angular and irregular bodies of every possible shape. Sandy soil has relatively large particles, which do not cling together to produce a granular structure. The pore space between individual particles is large and water passes through freely, but the total percentage of pore space is less than is found in a finer-textured soil, like clay. Water enters clay slowly, and also moves through it in like manner; but the water-holding capacity of this soil is considerable on account of its numerous small particles each of which holds a film of water about itself. Loam is more or less midway between sand and clay. There are some large particles that function separately as in sand. This facilitates drainage. There are also other medium-sized ones which form nuclei around which smaller ones collect, thus helping along soil granulation. The small spaces between the finer particles serve to retain a supply of water. Particles of partly decayed organic matter are also present in the loam soil. These serve to hold a supply of water. They also expand and contract considerably, thus moving other soil particles and lightening the whole mass of soil, so that air may circulate more freely and render conditions more favorable for plant growth.

Very sandy soils have a low absorptive capacity and allow water to move through them so freely that the water-soluble nutrient elements are easily leached out. As a consequence, such soils usually require much readily available fertilizer to produce satisfactory yields of cotton. If rains are not frequent, plants will suffer from lack of water. Heavy clay soils hold moisture so well that plants often suffer from excess of water in the soil or lack of proper aeration for their roots. Loam soils, being largely a mixture of other soils, are medium in water-holding and aeration capacities and are thus better suited to cotton plants.

**Soil Provinces and Regions of the Cotton Belt.**—A study of the soils in the provinces and regions represented in the Cotton Belt reveals the presence of a large number of types. No attempt will be made in this brief discussion to consider or even mention all the different types.

**Important Soils of the Atlantic and Gulf Coastal Plain.**—The part of this soil province within the Cotton Belt extends from southern Virginia southward to southern Florida and along the Gulf of Mexico to the mouth of the Rio Grande River. In North Carolina the province is about 400 miles wide. Toward the Mississippi River it widens and extends northward to Kentucky. West of the river it covers much of Arkansas, Louisiana, and Texas. In the soils map (Fig. 48) this province covers the parts indicated as Atlantic Coast Flatwoods, Florida Flatwoods, Middle Coastal Plain, Upper Coastal Plain, Clay Hills, Sand Hills, Black Prairies, Mississippi Bluffs and Silt-loam Uplands,

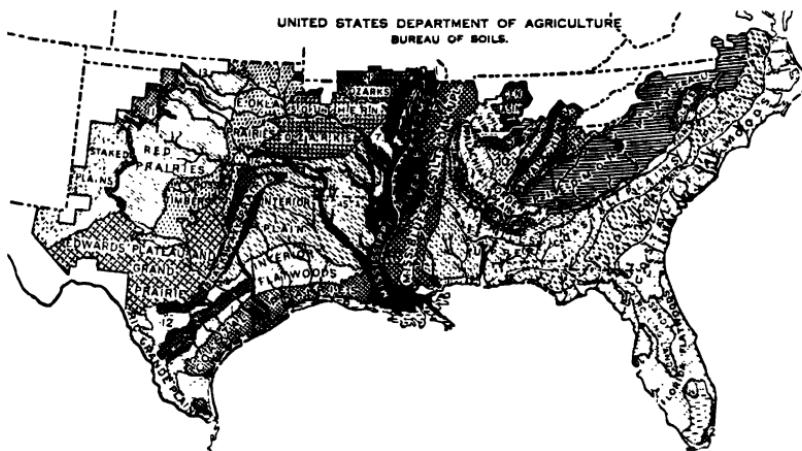


FIG. 48.—Soil regions of the cotton belt. (After Bennett.)

Interior Flatwoods, Interior Coastal Plain, Black Waxy Prairies, and certain other small districts. The land is rather flat or gently rolling. The soils are mainly sandy with more or less loam or clay in various mixtures. The following discussion of various parts of the Coastal Plain Province is from Bennett.<sup>2</sup>

*Atlantic Coast Flatwoods.*—This region extends along the coast of the Carolinas and Georgia, and over all of the state of Florida except the northwestern part (see Fig. 48). The area is about 21,200,000 acres; elevation is from sea level to 150 feet; surface is flat to undulating with many swamps and much poorly drained land; soils are mainly dark and grayish sands or sandy loams with yellow, gray, and mottled sand and clay subsoils. There is considerable silt loam in northeastern North Carolina.

The vegetation is principally open forests of long-leaf pine, with gallberry and grassy undergrowth. Fertilizers are used extensively. The average yield of cotton per acre is about 200 pounds of lint, and the average production for the area is about 290,000 bales.\*

*Florida and South Mississippi Flatwoods.*—The area of this region is about 15,000,000 acres. The deep sandy soils are dark and grayish to white; vegetation is long-leaf pine with saw palmetto undergrowth. But little cotton is grown.

*Middle Coastal Plain.*—This region extends across the Carolinas and Georgia into western Florida. Its area is 20,600,000 acres; elevation, mostly between 100 and 400 feet; surface, gently rolling; soils, mainly grayish sandy loams with yellow friable subsoils; vegetation, long-leaf pine and wire grass. The average yield of cotton per acre is about 205 pounds of lint, with an annual production for the region of 1,140,000 bales. Commercial fertilizers are used extensively.

*Upper Coastal Plain.*—This is a comparatively large region, having an area of 28,700,000 acres, and extending from South Carolina, across central Georgia, and southern Alabama into central Mississippi. The elevation is 20 to 500 feet; surface, rolling; soils, mainly grayish and reddish sandy loams with yellow and red friable, sandy clay subsoils; vegetation, long-leaf pine, short-leaf pine, and some oak and hickory. The average yield of cotton per acre is about 190 pounds, and the annual production 1,130,000 bales. Much fertilizer is used.

*Clay Hills.*—This region extends from western Georgia through Alabama and Mississippi almost to the Tennessee line. The total area is 8,000,000 acres; surface is hilly; some of the land is rough and stony and is known as "white rock" land in east central Mississippi and in western Alabama; subsoil is stiff clay. The average yield of lint cotton in this region is about 145 pounds, and the annual production is 320,000 bales.

*Sand Hills.*—This is a narrow soil belt extending along the upper margin of the Coastal Plain from central North Carolina, across South Carolina and Georgia into Alabama; area, 3,400,000 acres; soil, mainly deep, loose sand, grayish at the surface and yellowish beneath; vegetation, long-leaf pine and forked-leaf

\* Figures of the average yield per acre of lint cotton are from the four census years 1879, 1889, 1899, and 1909, unless otherwise noted. Figures of average production are for the five years, 1911 to 1915.

black-jack oak. Fertilizer is used extensively. The average yield of cotton per acre is about 180 pounds, and the annual production is 175,000 bales.

*Black Prairies.*—This crescent-shaped belt, extending from eastern Alabama into northeastern Mississippi, contains about 4,000,000 acres. Its elevation is 200 to 500 feet; surface, gently rolling with some flat "post-oak land;" soils, mainly dark-gray and brown limey clays. The "postoak" soils are brown sandy loams and clays with reddish subsoils, and contain less lime. The yield of cotton per acre averages less than 150 pounds, owing largely to continuous cropping and poor cultural practices. This area was originally considered one of the best in the Cotton Belt. The annual production is 235,000 bales.

*Mississippi Bluffs and Silt-loam Uplands.*—This division borders the Mississippi bottom lands on the east and extends from Louisiana into Kentucky. The area is 16,800,000 acres; elevation, 100 to 600 feet; surface, level to undulating and badly gullied in places; soils, mainly brown silt loams of loessial origin, which become thinner toward the eastern border. A narrow strip of the same soil occupies Crowley's Ridge, extending from southeastern Missouri to Marianna, Ark.; trees, principally oak, sweet gum, and poplar. The yield of cotton is about 200 pounds per acre, and total production is 586,000 bales annually.

*Interior Flatwoods.*—The largest area of the Interior Flatwoods extends from the Mississippi bottoms in Louisiana to the Guadalupe River in Texas. A long, narrow, crescent-shaped belt extending from central Alabama into northeastern Mississippi has similar soils and topography. The total area, including 200,000 acres in Alabama and Mississippi, is 13,000,000 acres; elevation, 100 to 500 feet; surface, prevailingly flat with much poorly drained land; soils, mainly gray sandy loams, silt loams, and clays with compact gray and yellow mottled subsoils; trees, long-leaf pine in Louisiana and Texas, and post oak in central Texas, Alabama, and Mississippi. The yield of cotton is about 175 pounds per acre, and annual production is 366,000 bales.

*Interior Coastal Plain.*—This region covers a large area of prevailingly rolling country in northeastern Texas, northwestern Louisiana, and southwestern Arkansas. The area is about 28,800,000 acres; elevation, 100 to 500 feet; soils, mainly grayish, brownish, or reddish sandy loams, sands, and clays; trees in the east, long-leaf pine, short-leaf pine, and some oak. The average

yield of cotton per acre is about 164 pounds, and the total production is 995,000 bales.

*Black Waxy Prairies.*—There are two main bodies of these prairies in Texas, one extending from the Red River in northeast Texas to San Antonio and the other from the Brazos River nearly to Laredo. The area of the first belt is 8,400,000 acres, and of the second, 4,900,000; elevation, 100 to 600 feet; surface, flat to undulating with good drainage; soils, black and dark-gray calcareous clays. There is a small belt of similar soils in southeastern Oklahoma and southwestern Arkansas. The average yield of cotton per acre is about 175 pounds, and the average production is 1,320,000 bales.

*Less Important Areas of the Coastal Plain.*—These include the *Sandy Rolling Lands of Interior Florida*, which contain some red and brown loamy hammock lands, where Sea Island was formerly grown to some extent; the *Appalachian Border of the Coastal Plain* in northern Alabama and northeastern Mississippi, a region of rolling to hilly, grayish sandy loams, with yellow and red subsoils, supporting mixed pine and oak forests; the *Pontotoc Ridge in Mississippi*, which has soils similar to those of the Upper Coastal Plain; and the *Gulf Coastal Prairies* of Louisiana and Texas, which is a flat, imperfectly drained region of black, brown, and gray clays and loams with black, yellow, and gray mottled clay subsoils. The eastern portion of the Coastal Prairies is largely devoted to rice, and the western portion principally to grazing and to corn growing, with cotton ranking second in importance. The *Red Lands of Southwest Texas* produce some cotton in the northern portion. The soils are mainly reddish sandy loams, gravelly loams, and loams with red subsoils.

**Alluvial Soil Regions.**—These regions include all alluvial soil along the rivers east of the great Plains Region. The soil is "made land," having been deposited by the adjacent rivers, and is naturally productive.

*Alluvial Bottoms of the Mississippi and Other Rivers.*—This region includes as its principal area the bottoms of the Mississippi River from Cairo, Ill., to the Gulf. It also includes the bottoms of all other rivers within the Cotton Belt, many of which are too small to show on the map. Much of the land is subject to overflow and requires the protection of levees. The area of the district is about 16,500,000 acres; elevation, sea level to 300 feet; surface, level. The soils of the Mississippi bottoms are mainly

brown or mottled clays, silt loams, and fine sandy loams, with gray, light-brown, and mottled subsoils. Characteristic trees are cypress, red gum, and oak. Annual production of cotton is about 940,000 bales. The most important cotton-growing section of this region is that known as the Yazoo-Mississippi Delta, in Mississippi, in which the average yield of cotton per acre is about 265 pounds, the highest in the Cotton Belt. In the bottoms of the streams east of the Mississippi River the principal soils are brownish loams, silt loams, and fine sandy loams, with yellowish and mottled subsoils. West of the Mississippi the principal soils are chocolate-red, brown, and black loams, silt loams, and clays, usually calcareous.

*Mississippi River Second Bottoms and Silty Prairies.*—These second bottoms are extensively developed in southeastern Missouri and northeastern Arkansas. They lie above overflow. The important soils are brown and gray silt loams, and fine sandy loams with light-brown, gray, and mottled subsoils. The gray soils are poorly drained. The better-drained soils are extensively used for cotton and give good yields.

**Important Soil Regions of the Piedmont, Appalachian, and Ozark Plateaus, Mountains, and Valleys.**—These regions are hilly to rolling. The soil is chiefly residual and not especially rich. The parts of most importance for cotton growing are discussed in the following paragraphs.

*Piedmont Plateau.*—This region extends from New York City southwestward to Alabama, but is planted in cotton only from North Carolina southward; area in the Cotton Belt, 26,700,000 acres; elevation 100 to 1,500 feet; surface, rolling to hilly; the cultivated slopes often require terracing to prevent erosion; soils, red-clay loams, and grayish sandy loams, with red- or yellow-clay subsoils, derived principally from granite, schist, and diorite; trees, largely oak, short-leaf pine, and hickory. The average yield of cotton per acre is about 180 pounds, and the average production is about 1,860,000 bales. Fertilizer is used extensively. In the Carolina state belt portion of the Piedmont, the principal soils are gray silt and slate loams and red-clay loam, with yellow- and red-clay subsoils. Fair to good yields of cotton are made, depending on fertilization.

Less important cotton regions are the Appalachian Limestone Valleys, including the Tennessee River Valley of northern Alabama, and the Central Basin in Tennessee. These are regions

of fertile, brown, reddish, and gray loams, silt loams, and clay loams, with reddish and yellowish subsoils, largely derived from limestone and are often cherty. A little cotton is grown in the southern portion of the Highland Rim region, which has gray silty and stony soils; and also in the valleys and smooth uplands of the southern Ozarks of Arkansas and eastern Oklahoma, which is a hilly to mountainous region, having brownish or reddish sandy-loam soils, often stony, with red sandy-clay subsoils.

**Important Soil Regions of the Western Prairies and Plains.**—The lack of sufficient rainfall limits greatly the production of cotton in parts of the Western Prairies and Plains within the Cotton Belt. Their soils are residual and fairly rich.

*Eastern Oklahoma Prairies.*—This region extends northward from the Red River in south central Oklahoma, and includes most of the eastern half of the state. It is used principally for growing corn and hay and for grazing cattle. The area in the Cotton Belt is about 11,000,000 acres; elevation, 800 to 1,200 feet; surface gently rolling, with some rough areas; soils, mainly brown, black, and reddish loams, clays and stony loams with clay subsoils, often of a clay-pan nature; vegetation, prairie grasses with occasional areas of post oak and black-jack oak and red cedar. Yield of seed cotton in 1909 was 182 pounds per acre; the average production is 350,000 bales.

*Red Prairies.*—This region extends across western Oklahoma into north central Texas, and is largely devoted to grazing, but has recently experienced extensive development in cotton production; area, 31,700,000 acres; elevation, 1,000 to 2,000 feet; surface, undulating to rolling with many rough eroded areas along the western margin. Soils are mainly red and brown fine sandy loams, silt and clay loams, with red- and brown-clay subsoils, often of a clay-pan nature. Included in this region are small "sand hill" areas (dunes). The yield of cotton per acre in 1909 was 105 pounds; the average production is 825,000 bales.

*Edwards Plateau and Grand Prairie.*—This region extends from central Texas westward to the Rio Grande River, but only the eastern portion is extensively used for the production of cotton. The area of the portion east of the Colorado River is 7,400,000 acres; elevation of the eastern part, 1,000 to 2,000 feet; surface, rolling to hilly with some level lowlands; soils, mainly calcareous silt and clay loams, black, brown, gray, and red in color; vegetation, largely prairie and plains grasses with scattered post oak

and cedar. The average yield of cotton per acre in the eastern portion is about 115 pounds; the average production is 410,000 bales.

Less important regions are the East and the West Cross Timbers in north central Texas. The soils of both regions are mainly brown sandy loams, often stony, with reddish and yellowish subsoils; vegetation, mostly post oak and black-jack oak. These regions are largely used for grazing cattle, but they produce some cotton.

**Cotton-soil Types.**—The soil provinces and regions mentioned in the foregoing pages contain many different soil types which have been given definite names. The most important of these, as outlined by Morgan,<sup>3</sup> are as follows:

Coastal Plain Province:

- Norfolk sand and fine sand
- Norfolk sandy loam and fine sandy loam
- Tifton sandy loam
- Orangeburg sand and fine sand
- Orangeburg sandy loam and fine sandy loam
- Greenville clay loam, sandy loam, gravelly sandy loam, and loamy sand
- Ruston fine sandy loam
- Susquehanna fine sandy loam
- Houston black clay, loam, and clay loam
- Houston clay
- Victoria clay, loam, and sandy loam
- Durant fine sandy loam

Piedmont Plateau:

- Cecil clay
- Cecil sandy loam
- Louisa slate loam, fine sandy loam, and loam

Appalachian Province:

- De Kalb fine sandy loam
- De Kalb silt loam
- Fayetteville fine sandy loam

Limestone Valleys and Uplands:

- Clarksville gravelly loam
- Clarksville silt loam
- Decatur clay loam
- Hagerstown loam

Loessial Region (Mississippi Bluffs and Silt Loam Uplands):

- Memphis silt loam

River Flood Plains Province:

- Miller fine sandy loam and clay loam
- Trinity clay
- Sharkey clay

Ocklocknee fine sandy loam and loam

Congaree loam

Kalmia fine sandy loam

Cahaba fine sandy loam

Great Plains Region:

Vernon fine sandy loam, loam, and silt loam

Crawford stony clay

Amarillo loam and silty clay loam

**Soils of Other Cotton-producing Regions.**—A brief mention of a few of the characteristics of the soils of other important cotton-producing regions of the world may be of some general interest and value.

*India.*—Smith<sup>8</sup> divides the soils in the more important cotton-producing regions of India into the following groups.

1. The "regur" or "cotton" soils, which are deep, limey, black, brown, or gray sticky clay soils, similar to the "black waxy" soils of the southern states and the "black adobe" of California. They are widely distributed over the large traprock area of central Bombay, northern Hyderabad, Berar, the western portion of the Central India Agency, and most of the peninsula of Kathiawar. These soils also occur in portions of southern Madras and cover much of the alluvial plain in Bombay, extending from south of Surat to Ahmadabad. Owing, in large measure, to more or less continuous cultivation for at least 2,000 years without fertilizer or manure, the yield of cotton per acre is less than 100 pounds of lint.

2. The "red soils," which are derived from crystalline rocks, are mainly of a sandy-clay texture. They cover most of the Madras Presidency, eastern Hyderabad, and Orissa, and though varying greatly in composition, they are, in general, less fertile than the regur soils.

3. The alluvium of the Indo-Gangetic Plain and of the upper valleys of the Nerbudda and the Tapti rivers. These soils consist mostly of reddish, brownish, or yellowish clay, often sandy, especially in the Indus Plain, rich in lime and potash.

*Egypt.*—Cotton lands in Egypt are limited almost wholly to alluvial soil along the Nile River and in its delta. The silt-laden waters of the river in a conjunction with the berseem clover grown in rotations keep this land very productive.

*Central, Western, and Eastern Africa.*—Vast areas in the Sudan south of Egypt are suitable to cotton production, in so far as soil conditions are concerned. Lack of labor and transportation facilities stand in the way of their usage at present. It is estimated that there are 25,000,000 acres in Nigeria and Kamerun

adapted to the raising of cotton. Other suitable areas are found in Uganda, in East Central Africa, British and German East Africa, Nyasaland, and Rhodesia.

*South America.*—It is estimated that Brazil has 30,000,000 acres or more of fertile land adapted to cotton raising. Much of this is virgin soil. Argentina has extensive areas. Peru has only limited areas in narrow coastal valleys. This land must be irrigated, but it is productive and the cotton crop of Peru is considerable.

*Asia Minor and Persia, Russia, China and Chosen, Mexico, and the West Indies.*—These countries all have lands adapted to cotton growing, and much can be produced when conditions demand it.

**Soil and Climatic Adaptations of the Cotton Plant.**—It is well known that certain kinds of cotton will yield much better in particular regions than other kinds. Sea Island cotton, for instance, did well in eastern South Carolina, Georgia, and Florida, prior to the coming of the boll weevil, but in no other part of the Cotton Belt has it been profitable, and it is not suited to many other cotton districts of the world. Egyptian cotton seems to be particularly adapted to the dry, hot, irrigated regions of Egypt and Arizona. Express, Delfos, and some other long-staple varieties of similar type are prized in the Yazoo-Mississippi Delta, but are not at all satisfactory in Texas or in several other parts of the Cotton Belt. Triumph, Lone Star, and Rowden, which are vigorous-growing, big-boll, short-staple varieties, are especially fitted to Texas and Oklahoma conditions. Trice yields well on the rich buckshot soils at Trail Lake, Miss. but does poorly on the thin clay-loam soils at Heathman, only 20 miles distant.

Very little investigational work has been carried on to determine definitely the reasons for particular cotton adaptations. It is very probable, however, that the adaptations mentioned above are influenced more by the climate, temperature, and rainfall than by soils. The two influences are so combined that it is impossible to attach the proper weight to each without careful research.

**Effect of the Soil Fertility on Length and Character of Staple.**—This is another subject on which there is a dearth of reliable data. Cotton buyers consider that the character of staple from different soil regions varies considerably, but nothing very

definite is known—only their impression without accurate measure.

The average length of the staple of thirteen varieties grown on thin hill land by the Mississippi Experiment Station<sup>4</sup> at A. and M. College, Mississippi, in 1921, was 0.95 inch. The average length of the same varieties grown the same year on medium-fertile valley land about  $\frac{1}{4}$  mile distant was 1.01 inches. The seed planted in both fields was from the same source. There were many poorly developed bolls on the hill-land cotton. These naturally had shorter and weaker staple. Well-developed bolls from plants grown on unfertile land appear to have practically as long and as strong fiber as similar bolls of the same variety produced on fertile land. The difference is brought about by the relative percentage of good and poor bolls. The average length of the staple of 585 bales of Express-350 cotton grown by Hardie and Percy on fertile buckshot land at Trail Lake, Miss., in 1922, was 1.153 inches. The average staple length of 396 bales of the same strain of cotton (seed from the same source) grown by the Robertshaw Company, on thin clay loam at Heathman, Miss., was 1.112 inches.

In most sections of the Cotton Belt an application of barn manure or of proper chemical fertilizers invigorates cotton plants and is thought to result in slightly longer and stronger staple. But in Egypt it is believed that a heavy application of barn manure to soil will prolong vegetative growth and injure the character of the lint. Phosphates are thought to hasten maturity and thus improve the staple.

**Effect of Soil Fertility on Lint Percentage.**—Cotton plants on rich soil grow vigorously and become considerably larger than plants on less fertile land. The seeds are larger and heavier. This results in a lower lint percentage. The average lint percentage of fourteen varieties grown on poor soil at Heathman, Miss., in 1922, was 33.4 per cent. The average on richer soil at Trail Lake was 30.5 per cent.

Ewing<sup>5</sup> found that the use of 100 pounds of nitrate of soda on Delta soil at Scott, Miss., decreased lint percentage 0.39 per cent.

#### CLIMATE

Cotton plants are found growing wild in the tropical and warm temperate zones of both hemispheres. Being a native of a warm climate, the growing of cotton as a commercial crop is

naturally limited to such climates. In the United States but very little cotton is grown north of latitude 37°. This is near the northern boundary of North Carolina. At times, as, for instance, during the Civil War, when the price of cotton was very high, a considerable amount was grown north of the latitude mentioned. But it is only during very favorable seasons or under the stimulus of high values that cotton production in this region can be profitable.

The states north of the thirty-seventh parallel have a growing season too short for cotton to mature and the mean temperature is too low. According to Whitney,<sup>6</sup> the mean temperature for the year is about 15° higher in South Carolina, Georgia, and Mississippi than in Massachusetts, New York, and Pennsylvania. The South has a mean summer temperature about 10° warmer and a winter temperature about 20° warmer than the North. This indicates a longer and warmer growing season in the South. The daily range of temperature is about the same in the two regions, with an increase in both as distance from the seacoast increases.

Whitney,<sup>6</sup> in discussing the climate of the United States, says:

The mean annual rainfall for the northern section of the United States is about 40 inches, while in the South that amount is exceeded by some 16 or 17 inches. The rainfall in both sections generally increases from the winter, reaching a maximum about the middle of summer, the autumn being the driest period. This larger rainfall and higher temperature of the South give considerably more moisture in the air. The temperature of the dew point in the South is 10 or 12° higher than in the northern states, and a given volume of air contains nearly twice as much moisture. But as the amount of moisture which the air is capable of holding increases with the temperature, the per cent of the saturating quantity or the relative humidity is about the same in the South as in the northern states mentioned. The relative humidity varies somewhat throughout the year, but it is slightly greater during the summer in the South than in the North.

The period of maximum precipitation, as mentioned by Whitney above, applies more particularly to the eastern states. For the central and western states of the Cotton Belt, the heaviest rainfall occurs from March to May (see Figs. 49 and 50). The average annual precipitation for the belt, according to the Weather Bureau, U. S. Department of Agriculture,<sup>7</sup> ranges from 23 inches in western Oklahoma and Texas to 55 inches in eastern

North Carolina and 60 inches in southern Mississippi. Throughout much of the area the range is from 30 to 50 inches (see Fig. 51). The spring rainfall ranges from 6 inches in western Texas to 16 inches in Arkansas and southern Mississippi, being heavier in the Mississippi Valley states than in Texas or the South Atlantic states. Summer rains are moderate in the central states and heavier toward the southeast and east, reaching a maximum of 20 inches in southern Mississippi and in eastern North Carolina and eastern South Carolina. The Black Prairie of Texas receives only an average of 8 inches of summer rainfall. Autumn is the driest season of the year for the belt, the rainfall for the fall months being less than 10 inches in nearly every region. The Cotton Belt has an average summer temperature of 77° along the northern boundary. This, as pointed out by the Weather Bureau of U. S. Department of Agriculture, appears to be the limit beyond which commercial production of cotton becomes unprofitable. In the southern part of the Cotton Belt, the average temperature is 80 to 85°, and in the Imperial Valley of California it averages 95°. Along the northern margin of the Cotton Belt the last killing frost in the spring is, on the average, about Apr. 10, and the first killing frost in the fall about Oct. 25, the growing season for cotton being about 200 days. In the southern portion of the Cotton Belt the last killing frost comes about Mar. 10, on the average, and the first killing frost in the fall about Nov. 25. This gives a growing season of about 260 days (see Fig. 54). The extra length of frostless season in the southern part of the belt, however, is of very little consequence, on account of the prevalence of the boll weevil. No cotton is produced after the first of August, as a rule. Larger yields are to be obtained where the growing season is long, but as weevil infestation is heavy during the latter half of the growing season in most areas of the belt, only early developing varieties can be used advantageously—varieties that will mature bolls beyond weevil damage within a period of 110 days.

**Optimum Weather Conditions for Making a Cotton Crop.—** Most of the land that is to be planted in cotton is flat broken or broken by listing and bedding prior to the middle of April. On the large cotton plantations this work starts as soon as the cotton of the preceding crop is picked, and continues during the winter and spring season, or until completed. There is not enough freezing weather during the winter to impede greatly

the progress of this work, but there is very commonly too much rain. Land should be dry enough to crumble freely when turned, and for this condition to prevail rainfall must be only moderate. Occasional rains are needed in April to firm the beds that have been made and to moisten hard, cloddy soil, so that it may be well pulverized in preparation of seed bed.

Frequent warm showers are desirable at planting time. Cotton seed cannot be planted deep, and consequently frequent rains are helpful to keep the surface of the soil moist. Continued

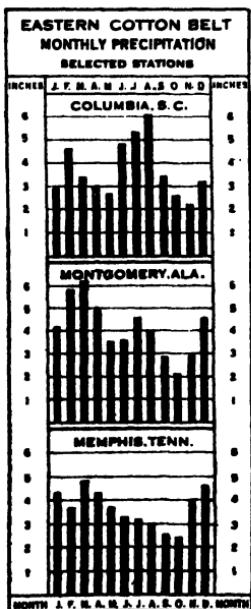


FIG. 49.—Monthly precipitation at selected stations in the eastern part of the Cotton Belt. (After Weather Bureau, U. S. Department of Agriculture.)

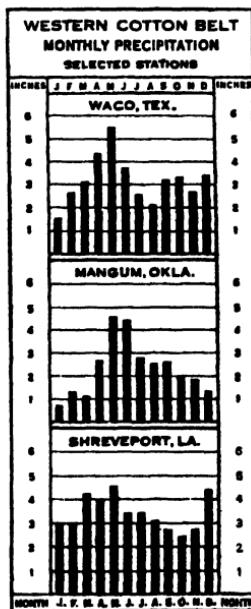


FIG. 50.—Monthly precipitation at selected stations in the western part of the Cotton Belt. (After Weather Bureau, U. S. Department of Agriculture.)

heavy rains are harmful, especially if accompanied by cool weather. Cotton seed to germinate well must be moist but not wet. If kept wet any length of time, they rot in the ground instead of germinating. If the rainfall is scanty and there are drying winds, the surface of the soil may become so dry that the seed will not secure enough moisture to start growth. After the young plant is above the surface of the soil, cool weather retards its growth and root development; drying winds draw water from its tissues and cause a collapse of a part of its cells, thereby

bringing about a disorganization. This is apt to result in a stunting of the plant and a permanent injury to its structure.

From about the middle of May to about the middle of August the cotton plant is in the period of active vegetative growth. During this time best growth is made if a warm shower occurs about once a week. Where boll weevils are numerous, comparatively dry weather from the latter part of June until the first part of August is desirable. This retards the growth of plants to some extent, but its beneficial influence in preventing the multiplication of the weevils more than overbalances the harmful effect. Rainy weather during the growing period not only leads to worse weevil damage but induces the production of too much "weed," or vegetative growth; it makes proper cultivation

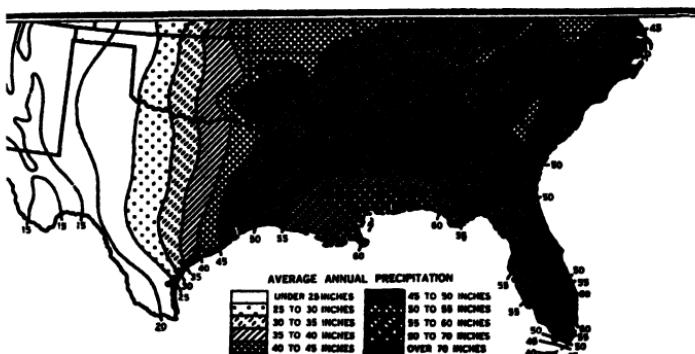


FIG. 51.—Average annual precipitation in the Cotton Belt. (After Weather Bureau, U. S. Department of Agriculture.)

impossible, so that grass and weeds have free rein; the cotton plants develop numerous roots near the surface instead of sending them deep into the soil, as they normally do. With only the shallow roots to depend on, the plants suffer from lack of water if dry weather ensues later in the season. Squares, young bolls, and a part of the leaves may be shed as a result. Cotton plants will not make much growth if there is an excess of water in the soil. This excess of water lowers the temperature of the soil, prevents proper aeration, and interferes with the regular upward movement of the capillary water; it is this water that carries to the plant roots their mineral nutrients, both from fertilizers and from the natural soil ingredients.

An abundance of sunshine and warm uniform temperature during the growth period is desirable. Cold periods or wide

contrasts between day and night temperatures injure the plants and tend to cause them to check growth and mature prematurely. Rains during the day while blooms are open interfere with pollination and cause some shedding.

During the ripening period, extending from August to October, the fruit that had started to develop comes to maturity and most of the bolls open. Vegetative growth should cease and the foods that have been elaborated by the plant and stored in its tissues are used in the production of seed and lint. Dry weather

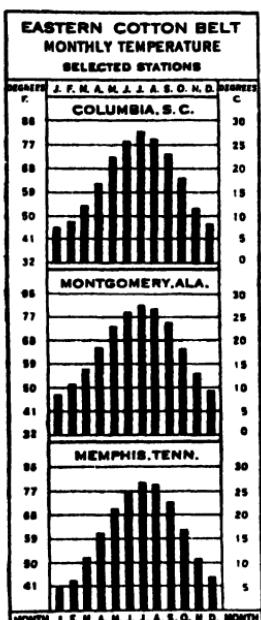


FIG. 52.—Monthly temperature at selected stations in the eastern part of the Cotton Belt. (After Weather Bureau, U. S. Department of Agriculture.)

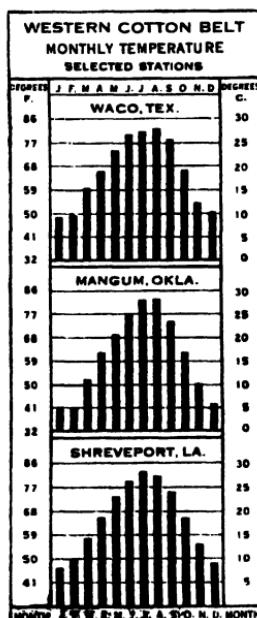


FIG. 53.—Monthly temperature at selected stations in the western part of the Cotton Belt. (After Weather Bureau, U. S. Department of Agriculture.)

is best for this period, and, fortunately, autumn is the driest period of the year in most parts of the Cotton Belt. Dry weather checks vegetative growth, stimulates fruiting, prevents boll rot, and allows the seed cotton to be picked before the lint is damaged. During the ripening period the range in temperature between day and night is considerable. This variation also assists in checking vegetative growth and hastening maturity.

The picking season extends from August to November or later. Rainless, sunny days are desired during this period. Rains

discolor the lint of open bolls, and rains and wind together cause many locks to fall to the ground, which soils the lint. Frequent or daily rains cause seed to sprout in the boll and result in much boll rot, even in open bolls. Prior to the advent of the boll weevil, it was very important that killing frosts should not come until late in November, the late bolls thus being allowed a chance to mature. With weevils prevalent nearly everywhere, but few bolls set after the first of September amount to anything. The grade of the lint cotton is somewhat better if frosts are late. The leaves crumble after frosts fall, and some of the pieces lodge in the lint. Early frosts produce much tinged, stained, or discolored cotton if there are many late bolls.

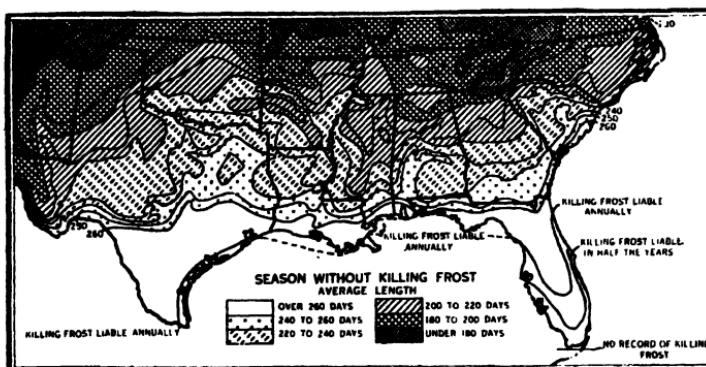


FIG. 54.—Season without killing frost in the Cotton Belt. (After the Bureau, U. S. Department of Agriculture.)

**Climate of Other Leading Cotton-growing Regions of the World.**—The United States leads the world in cotton production. The question is often raised as to whether there is something in the soil or climatic conditions of the Cotton Belt that especially fit it for growing cotton. Several other lands possess as fertile or even more fertile soils. The difference is evidently not due to the soils. The matter of better climatic adaptations probably has some weight. The southern states appear to have a more uniform distribution of rainfall through the year than do most other cotton-growing countries. There is probably some advantage, too, in the gradual change of temperature here from summer to autumn.

**West Indies.**—According to Mell,<sup>9</sup> from whom this discussion of the climate of foreign countries is largely taken, the West Indies have a temperature that ranges between 77 and 82°, and

frosts are very infrequent. A short, wet season begins in April and lasts from 2 to 6 weeks; this is followed by a dry season, during which the thermometer remains about 80°. The heat is very oppressive during July and August, and the summer is dry. The main rainy season begins about Oct. 1 and lasts until December. Following this there is a dry spell that lasts until April. The annual rainfall is 63 inches.

*India.*—The territory of India is so extensive that there are marked climatic differences in different sections. The climate of a large part of the country is greatly influenced by the two annual monsoons that flow from the northeast and southwest. Such great extremes of moisture and temperature precede or accompany these monsoons that the cotton plants growing in the regions covered are subjected to very hard conditions.

The mean annual temperature of Bombay for the cotton year, from February until June, is 90°. The mean monthly temperature at Calcutta ranges from 66° in January to 85.7° in May. The winter mean is 67.3°; the spring, 83.7°; the summer, 82.5°; and the autumn, 78.5°. The mean annual temperature at Madras is 86.6°; at Benares, 80.3; at Cawnpore, 80°, at Dehra Dun, 70.5°.

The monthly precipitation at Madras is as follows:

	INCHES		INCHES
January.....	1.33	July.....	3.20
February.....	0.23	August.....	5.24
March.....	0.36	September.....	4.76
April.....	0.63	October.....	10.09
May.....	1.03	November.....	12.43
June.....	2.03	December.....	3.25

The annual precipitation at several stations in India is as follows:

	INCHES
Bombay.....	68.73
Tunna.....	106.16
Dapolee.....	134.96
Mahabaleshwar.....	254.84
Poona.....	19.02
Dharwar.....	38.81
Madras.....	43.58

Some parts of India, especially the northern part, are mainly dependent on irrigation, while other parts have sufficient rainfall.

*Mexico.*—Cotton is grown, in small quantities at least, throughout nearly the whole of Mexico. There is an abundance of rainfall along the Pacific coast. Irrigation is possible in much of the interior. The temperature is mild and very uniform over most of the country. At Vera Cruz the mean monthly temperatures run as follows:

	DEGREES FAHRENHEIT		DEGREES FAHRENHEIT
January.....	70.0	July.....	81.5
February.....	71.6	August.....	82.4
March.....	73.4	September.....	81.0
April.....	72.2	October.....	78.4
May.....	80.5	November.....	75.4
June.....	81.9	December.....	71.1

*Australia.*—Frosts in Australia are so light that cotton plants grow on from year to year. The temperature for the cotton months, which are September to June, ranges from 60 to 100°. The mean annual temperature at Sydney is 62.4°; at Victoria it is 56.8°. The rainfall at Melbourne is 25.66 inches.

*Brazil.*—The climate of Brazil is in some respects well suited to growing cotton. Plants bear fruit throughout the year. Planting is done in November. The first flowers open in June, and flowering continues the rest of the year. Mell<sup>9</sup> says:

At the city of Rio de Janciro, which is situated on the boundary line of the torrid and temperate zones, the average temperature, according to the *Annuario de Imperial Observatorio* for 1887, is 74.1°F. These figures are the average for 36 years. Only two seasons are known here, summer, or the rainy season, which lasts from October to the end of March, and winter, or the dry season, which lasts from April to September. The average temperature of summer is about 78.8°, and that of winter 69.8°. The highest temperature noted was 99.5 and the lowest 50.3°.

The following meteorological data from selected stations in Brazil are taken from reports made by the Brazilian government.

TABLE XXV.—METEOROLOGICAL DATA FROM CERTAIN STATIONS IN BRAZIL

Stations	Latitude	Altitude, feet	Mean annual temperature, degrees Fahrenheit	Maximum temperature, degrees Fahrenheit	Minimum temperature, degrees Fahrenheit	Annual rainfall, inches
Maranhão, Maranhão.....	1° 27'	142	81.32	92.84	69.98	96.65
Amarante, Parnahyba.....	6° 13'	.....	80.78	95.90	64.40	6.30
Bahia, Bahia.....	12° 58'	210	78.80	88.70	35.78	85.16
Santa Cruz, Rio de Janeiro.....	22° 56'	85	71.96	97.88	66.56	184.33
Passo-Fundo, Santa Catharina.....	28° 28'	2,060	62.78	93.92	32.00	
Rio Grande do Sul.....	32° 00'	52	65.84	90.32	33.80	35.91

*Argentina.*—The climate of Argentina is very similar to that of the United States, as shown by Mell<sup>9</sup> in a quotation from Barnes of the U. S. Department of Agriculture:

The mean annual temperature of the Argentine Republic is about the same as that of the United States; that is to say, that both countries are included within the limits of similar isothermal lines, from 70 to about 40 in the latter country, exclusive of the Florida peninsula, and also from 70 to about 40 in the former. The average range of the thermometer is therefore about the same. Both are situated geographically and as to range of climate within so-called temperate zones, and, other things being equal, the character and range of productions of the two would be the same.

Climatic conditions vary greatly in different parts of Argentina. There is a range of altitude from sea level to the snow-capped peaks of the Andes. The southerly equatorial current moderates the climate of the southern portion.

Between the thirtieth and thirty-first parallels the region is subtropical, the temperature ranging from 66° on the eastern plains to 62.5° in Cordoba, and rainfall ranging from 2 inches in San Juan to 47 inches in Entre Ríos. In the vicinity of Buenos Aires, the mean annual temperature is about 63°, with a maximum of 104° and a minimum of 32°; the annual rainfall is 34 inches.

*Egypt*.—Upper Egypt, or the southern portion of the country, has practically no rainfall, while the region about the mouth of the Nile River has a rainfall of about 8 inches. The mean summer temperature in Lower Egypt ranges from 80 to 90°, and the winter from 50 to 60°. Cotton can be grown only by means of irrigation.

Table XXVI from Mell<sup>9</sup> shows the comparative temperature and rainfall of several of the leading cotton countries of the world.

TABLE XXVI.—COMPARATIVE TEMPERATURE AND RAINFALL OF CERTAIN COTTON-PRODUCING COUNTRIES

Countries	Temperature, degrees Fahrenheit			Annual precipi- tation, inches
	Mean annual	Mean spring	Mean summer	
United States (Cotton Belt).....	63.5	63.5	78.0	50.80
West Indies.....	79.5	78.9	78.5	63.00
British India.....	77.8	81.8	86.2	74.22
Mexico (Vera Cruz).....	76.6	75.3	82.0	
Australia (Sydney).....	59.6			
Brazil (Rio Grande do Sul).....	65.6	63.8	74.7	72.36
Argentine (Buenos Aires).....	61.2	69.9	73.6	32.06
Egypt, lower (Alexandria).....	....	....	76.6	7.51

Figure 55 shows graphically the mean monthly temperature and rainfall at eight different stations in important cotton-producing countries.

*Acclimatization*.—Cotton plants are very sensitive to climatic or weather changes. A variety moved from one region or country to another rarely produces well for a time, and may never do well under the new conditions. A period of dry weather following wet may cause a shedding of squares, bolls, and even leaves. Cold, wet weather during the spring or grass and weeds in the field may prevent proper growth of plants during the fore part of the season, but with the coming of good weather conditions the plants will react and make satisfactory growth and yields, provided they are cultivated properly and the fruiting season is not cut short by boll weevils or frosts. Cook<sup>11</sup> says:

Although many varieties show striking responses to new conditions, with very abnormal behavior in the first years, it is possible, with many varieties, to secure a high degree of adjustment to the new conditions,

with a normal and regular behavior of the plants, after a few years of acclimatization or local adjustment, assisted by a proper course of selection.

The range of adaptive possibilities is strikingly shown when a new type of cotton, distinct from any formerly grown in the United States, is able to thrive under many different conditions in widely separated regions. Thus, the Durango, a new Upland cotton, introduced only a few years ago from Mexico and acclimatized in Texas, has shown its ability to produce large crops of good fiber over almost the entire range of cotton cultivation in the United States.

### TEMPERATURE AND PRECIPITATION IN COTTON PRODUCING REGIONS

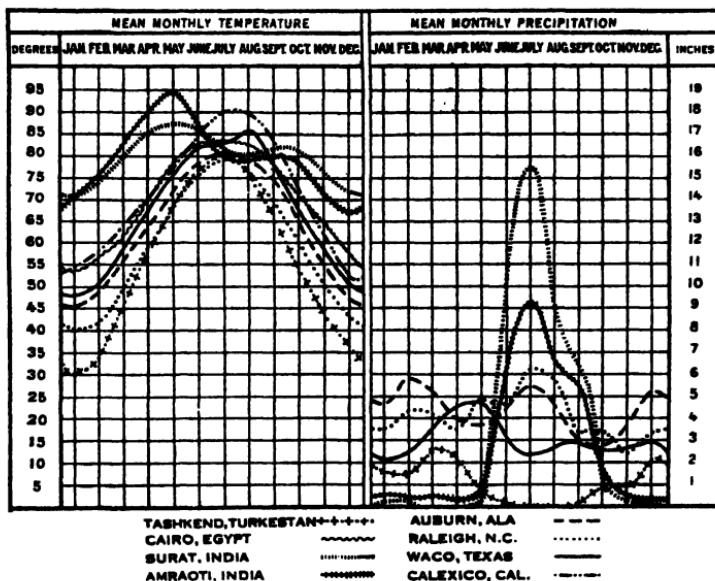


FIG. 55.—The summer temperatures in the various cotton-producing regions are similar, the mean July temperature being between 80 and 90°; and the distribution of precipitation, though varying greatly in amount at other seasons of the year, is similar in showing an October rainfall of 3 in. or less. Heavy rains in the fall interfere with picking and also injure the quality of the lint. (After Weather Bureau, U. S. Department of Agriculture.)

**Acclimatization Experiments.**—Duggar,<sup>10</sup> in 1898, sent seed of a certain strain of King cotton to Goldville, S. C., to Stillwater, Okla., and to Abbeyville and to Dillburg, Ala. The strain was also planted at Auburn the same year. The following year seed from the five sources were planted in a comparative test at Auburn, Ala. The differences in yield were not significant. It

was thought that one year was not sufficient time to affect the plants enough for differences to show in a later generation.

Winters, of the North Carolina Experiment Station, in 1913, saved seed from a certain plant growing in a field of King cotton near West Raleigh, N. C. In 1914 and 1915, progenies from this 1913 selection were grown at West Raleigh and the plants self-pollinated each year. In 1916, the seed of the strain were divided, a part being planted at Agricultural College, Miss., and the rest at West Raleigh, N. C. In 1917 and 1918, seed of the strain grown in Mississippi since 1916 were planted in rows alternating with rows planted with seed direct from North Carolina, and comparisons were made. It was found that the plants coming from Mississippi-grown seed were taller both at blooming time and at maturity, that they had more fruit branches, did more blooming, produced more bolls, and yielded more seed cotton than the plants grown from North Carolina-grown seed. The differences were not great, but they seemed to be consistent. The lint percentages of the two strains were about the same, but the staple of the Mississippi strain was slightly longer. At the North Carolina Station corresponding tests were made. There, also, plants from Mississippi-grown seed made best growth and slightly better yields.

**American Varieties in Foreign Countries.**—Since American varieties of cotton produce better in the United States than the native varieties grown in most of the cotton-producing countries of the world and have a better quality of staple, many attempts have been made to introduce American varieties elsewhere, but these attempts have very generally resulted in failures. They failed because the imported varieties were allowed to become mixed either in the field or at the gin; because of lack of uniform water supply; and because not sufficient chance was given the strains to become acclimated. The usual practice has been to import seed, grow the variety for a few years, or until it had deteriorated, and then to import a fresh supply of seed. Had selections been made and new strains developed from plants that had shown some adaptation to the new conditions, success might have been attained.

India has been importing and experimenting with American varieties since 1790, endeavoring to have them grown there, but over much of the country inferior native varieties are still in use. The Indian Cotton Committee appointed by the

Governor General in Council, in its report for 1919, recommended that the work of introducing acclimatized American varieties be continued in most sections of the country, but much stress was laid on improving irrigation facilities, establishing seed farms where pure seed of adapted strains could be increased, and improving marketing facilities so that growers of improved varieties, or varieties with better staple, could receive prices in keeping with the quality of cotton produced.

G. A. Gammie, formerly Imperial Cotton Specialist for India, says, "The trials with numerous American cottons show that they all require considerable acclimatization." T. S. Kuo, in the Report of the Cotton Experiment Stations of the Chinese Cotton Millowners' Association for 1920, says with reference to the use of American varieties in China,

In this country, Upland (American) varieties have been tried at many places for many years already. These trials convinced us that they can be grown successfully. All instances of deterioration so far alleged were due to the carelessness of mixing with inferior varieties and lack of selection. We believe those desirable varieties, such as Lone Star, Acala, etc., not only can be quickly acclimatized but will retain their good qualities infinitely if the line selection of the seed is strictly practiced.

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## CHAPTER XIII

### COTTON CULTURE

Considering the crop as a whole, it may be said that the cultural practices followed in growing cotton are poorer than those used in growing any other of the important agricultural crops. Morgan<sup>5</sup> mentions five probable reasons for this:

(1) A relatively large percentage of the cotton crop is produced on "one-horse" farms, where thorough plowing and the use of improved implements are impossible. (2) A scarcity of heavy draft animals is often the cause of poor tillage practices even on the large farms. (3) A large percentage of the acreage in cotton is tilled by renters rather than land owners. In most cases little or no supervision of farm operations is given by the land owner, and, as a result, very superficial tillage is practiced. (4) Many unprofitable practices employed in the early days of cotton production in the South have become more or less traditional, being handed down from one generation to the next. (5) Little knowledge of the fundamental principles underlying the growth and nutrition of crops.

Cultural practices vary considerably in different sections, owing to difference in soil, climate, insect pests, etc. In areas such as the Mississippi Delta, Ellis County, Texas, parts of South Carolina, and others, excellent practices are generally followed.

**Disposal of Stalks and Débris.**—The first step in the preparation of a good seed bed is the proper disposal of the vegetation on the land. In most cases cotton follows either corn or cotton, and if the crop has been good, there is a considerable mass of old stalks on the lands. Usually it is difficult to turn these under properly with a plow unless they have been cut or broken into short pieces. This is accomplished by running over them with a stalk cutter, the blades of which cut the stalks into short pieces, or by breaking them up more or less with a hoe or a club after they have become old and brittle. Where the growth of old stalks is very heavy, a disc harrow is sometimes used in addition to the stalk cutter. In too many instances old stalks are

cut, raked, and burned. This practice is to be condemned severely, because the organic matter, which the soil needs badly, is entirely lost. The nitrogen of the stalks, as well as a large part of the mineral nutrients, is also lost. The ashes from the burned stalks are leached out and largely carried away by water from heavy rains.

**Plowing by Flat Breaking.**—According to data collected by Cates<sup>1</sup> of the U. S. Department of Agriculture, a little more than one-half of the cotton land in the United States is plowed broadcast, or broken flat (see Table XXVII, columns 7 and 8). The work is done with one-, two-, three-, or four-horse, turning plows, or with heavy disc, sulky, or gang plows, such as are used in breaking land in the corn belt. The type and size of the plow used seem to depend largely on the section of the country and the topography of the land. On the level lands of Texas, Oklahoma, and Mississippi large plows and heavy teams are used,

TABLE XXVII.—TILLAGE PRACTICES WITH COTTON IN NINETEEN REGIONS SURVEYED, SHOWING DATA IN REGARD TO PLOWING (After Cates)

Region surveyed	Fall plowing		Spring plowing		Farmers plowing land		Plows used by farmers			
	County, state, etc.	Farmers practic-ing, per cent	Depth, inches	Farmers practic-ing, per cent	Depth, inches	Level, per cent	Into beds, per cent	One-horse, per cent	Two-horse, per cent	Three-horse, per cent
A Peninscot, Mo.	...	...	100	5	60	40	...	76	24	16
B Mississippi Delta	16	4	84	5	24	76	...	76	88	
C Robeson, N. C.	4	7.5	96	6.5	56	44	36	64		
D Mecklenburg, N. C.	52	6.5	48	5.5	80	20	4	88	8	
E Barnwell, S. C.	...	...	100	6	100	...	52	48		
F Pike, Ga.	56	6.5	44	5.5	80	20	12	88		
G Tift, Ga.	16	7.5	84	7	100	...	4	92	4	
H Giles, Tenn.	12	5	88	5.5	100	...	...	96	4	
I Bulloch, Ga.	...	...	100	7	96	4	32	68		
J St. Francis, Ark.	...	...	100	4	4	96	56	44		
K Ellis, Tex.	4	6	96	4	4	96	...	4	..	96
L Chambers, Ala.	...	...	100	5.5	72	28	28	72		
M Johnson, Okla.	8	4	92	4.5	60	40	...	60	36	4
N Jefferson, Fla.	8	10	92	4.5	52	48	48	52		
O Lincoln Parish, Louisiana	...	...	100	4.5	28	72	32	68		
P Lavaca, Tex.	68	5	32	5	...	100	...	80	..	20
Q Houston, Tex.	8	7	92	4	8	92	...	96	..	4
R Monroe, Miss.	4	3.5	96	5	20	80	12	84	..	48
S Bexar, Tex.	92	6	8	7	92	8	4 <sup>a</sup>	12	36	48

<sup>a</sup> Five-horse plow.

whereas on the uplands of the Carolinas, Georgia, Alabama, and Mississippi smaller turning plows are in use, many being one-horse. Flat breaking is advantageous in that none of the soil is left unbroken, but it is more expensive than breaking by bedding.

**Plowing by Bedding.**—Plowing by listing, or bedding, is extensively practiced in many parts of the Cotton Belt, even in regions where good cultural practices are followed. It is somewhat more speedy than flat breaking. Fields are covered more quickly, and it is not necessary to rebed or lay off rows prior to planting.

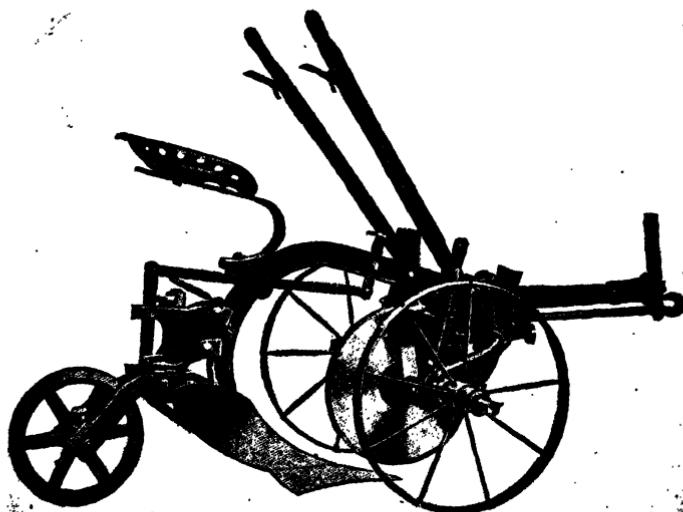


FIG. 56.—Uncle Sam Middle Burster. A heavy double mold board plow used in bedding cotton land. (*Courtesy B. F. Avery and Sons.*)

There are two general methods of bedding land: One is to use a heavy middle burster or lister requiring a heavy team of four or six mules. This method is used in Texas and in the Mississippi Delta and is becoming fairly general. The lister is run in the ridge of the old row and a new bed is made at each "through."

The second method is to use a turning plow of one-, two-, or three-horse size, various sizes being used in different sections. A furrow is made through the old middle and then one or two furrow slices are thrown toward it from each side. If but one furrow slice is thrown, there is a considerable strip, or "balk,"

left in the middle between the new ridges. This is thrown out with a middle burster.

On land that has been flat broken, low beds for planting are sometimes made with small disc harrows, or with cultivators with discs or shovels on them set to make a ridge. When large listing plows are used, such as the Avery "Uncle Sam" Four-mule Middle Burster (Fig. 56), good work is done. Apparently, the yield is much the same whether the land is bedded or broken broadcast, but probably more labor is required in cultivating the crop if the land is not flat broken. Land put into beds during the fall or winter dries out earlier in the spring, warms up sooner, and is in condition for planting at an earlier date. This makes an earlier crop possible. An early crop gives best returns in boll-weevil districts.

**Time of Plowing.**—According to the survey made by Cates,<sup>1</sup> most cotton land is plowed in the spring (Table XXVII). This practice varies considerably with the locality and the season, some winters being much more favorable for work than others. Where conditions will permit it, there are several advantages to be gained from fall or winter plowing: (1) It gives the planter a chance to get ahead with his work, so as to be able to plant his crop more quickly when suitable weather comes in the spring. (2) Vegetation turned under early has time to decay and to benefit the following crop. (3) Fresh soil brought up from the subsoil has time to weather and its important chemical elements become available to plants. (4) Insect pests are controlled in a measure.

In hilly regions where the land erodes badly, fall plowing is not advisable, nor is it possible if cover crops are grown.

**Depth of Plowing.**—Breaking for cotton is 3 to 8 inches deep, but far too much land is broken only 3 or 4 inches (see Table XXVII). Breaking is commonly somewhat deeper when done in the fall. Sandy soil is usually plowed more deeply than clay, since the plow runs more easily. Clay should be plowed to a depth of 6 to 8 inches for the best results. A deep layer of cultivated soil holds more moisture, and plants on it grow more vigorously. It is not advisable to plow deeply late in the spring. If dry weather ensues, the soil is apt to dry out to a depth of several inches, sufficient to interfere with the germination and growth of young plants. Sterile soil from the subsoil brought to the surface late in the spring does not have time to disintegrate,

but bakes, forms clods, and is troublesome during the season. If shallow plowing has been practiced, it is considered best to increase the depth gradually, say an inch a year, until a satisfactory depth is attained. Data secured by Cates<sup>1</sup> failed to show any correlation between depth of plowing and yields.

**Subsoiling.**—Subsoiling is a term applied to the loosening of the subsoil without bringing it to the surface. It is accomplished by running an ordinary turning plow, and following this, in the same furrow, with a special subsoiling plow which has no mold board and does not displace the soil. In a few experiments, subsoiling has shown profitable results, but on the whole it has not paid, and the process is to be considered of doubtful value.

**The Seed Bed.**—For cotton a firm but well-pulverized seed bed is always desirable. This may be secured by thoroughly pulverizing the soil some weeks before planting, letting it rest until a good rain has fallen to firm or settle it, and then freshening the surface by a light harrowing or dragging.

Land that is listed or bedded in the fall or winter will require freshening in the spring before planting. This is commonly accomplished by rebedding or by running over the bed with a deeply running harrow, such as a two-horse disc or a disc cultivator. After the beds have been freshened, they are pulverized and dragged down to a height of 6 inches or less with a spike-tooth harrow or a drag. Beds that have been made recently may be pulverized and dragged down to desired height with spike-tooth harrow or drag. Cotton planted late is sometimes planted on the level. In parts of Texas and Oklahoma and in a few other of the drier districts of the Cotton Belt, cotton is planted in lister furrows.

There is a considerable advantage to be gained in most places by planting cotton on beds or low ridges. Young cotton plants are tender and will not thrive if the land is wet or the weather cool. The top part of a ridge becomes dry sooner than level land, and, being drier and having more surface to the sun, becomes somewhat warmer.

**Time of Planting.**—The best date for planting cotton naturally varies in different places on account of climatic differences. Table XXVIII gives the range of planting dates for various parts of the Cotton Belt. These range from Mar. 1 for southern Texas to June 1 for the more northern regions, the average date being about Apr. 15.

TABLE XXVIII.—TILLAGE PRACTICES WITH COTTON IN NINETEEN REGIONS SURVEYED, SHOWING DATES AND METHODS OF PLANTING (After Cates)

Region surveyed (see Table XXVII)	Planting date		Farmers <sup>a</sup> planting, per cent		Average distance apart				Planters used by farmers, per cent		
	Average	Range	Level	On beds	Listing	Rows, feet	Hills, inches	Average space per hill, square feet	Seed per acre, pecks	One-horse	Two-horse
										Two- row	One-row
A	Apr. 21	Apr. 10-May 10	..	100	..	3.5	16	5	4	60	40
B	Apr. 11	Mar. 25-Apr. 30	16	84	..	4	17	6	4	96	4
C	Apr. 14	Apr. 8-Apr. 20	8	92	..	4	13	4	4	100	
D	Apr. 23	Apr. 15-May 5	..	100	..	3.5	12.5	3.5	4	100	
E	Apr. 11	Mar. 25-Apr. 30	..	100	..	4	15.5	5	4		
F	Apr. 15	Apr. 1-May 1	16	84	..	3.5	13	3.5	5	100	
G	Apr. 4	Mar. 15-Apr. 20	28	64	8	4	16.5	5.5	2.5	100	
H	Apr. 15	Mar. 10-Apr. 30	20	80	..	3	13	3.5	5.5	100	
I	Apr. 1	Mar. 15-Apr. 15	4	84	12	4	16.5	5.5	3	100	
J	Apr. 25	Apr. 1-May 20	4	96	..	3.5	14	4.5	5.5	100	
K	Apr. 13	Apr. 1-May 15	8	92	..	3	13	3.5	2.5	..	4 <sup>b</sup> 96
L	Apr. 11	Mar. 25-May 1	..	100	..	3.5	13.5	4	5	100	
M	Apr. 21	Apr. 1-June 8	16	64	20	3.5	15.5	4.5	2.5	64	4 32
N	Apr. 1	Mar. 1-Apr. 15	8	92	..	4	13	4	4	92	4 4 <sup>c</sup>
O	Apr. 18	Apr. 1-May 15	..	100	..	4	14	4.5	4	100	
P	Mar. 25	Mar. 1-May 1	..	100	..	3.5	13	4	5.5	8	.. 92
Q	Apr. 16	Mar. 30-May 30	4	96	..	3.5	12.5	3.5	3	92	.. 8
R	Apr. 15	Apr. 1-May 1	4	96	..	3.5	15	4.5	4	96	.. 4
S	Mar. 25	Mar. 1-Apr. 15	40	20	20	3.5	18.5	5.5	3	..	4 96

<sup>a</sup> All planted with drill.<sup>b</sup> Three-horse one-row planter.<sup>c</sup> Hand planter.

Ewing of Scott, Miss., planted cotton at 5-day intervals from Mar. 25 to about the middle of May for a series of years. The optimum date was found to be between Apr. 10 and 20, with but little difference in yields secured from plantings made at different times within those dates. Plantings made before or after those dates gave considerably less yield, and the farther removed from the date the lower the yield. These experiments were conducted at Scott, Miss., in the central part of the Mississippi Delta. Boll weevils were plentiful the latter part of the season.

The optimum date for planting in any particular regions varies in different years, on account of seasonal weather variation. This variation may be as much as 10 days or 2 weeks. Cotton should not be planted until danger of frost is over and the land

has become warm. If planted too early, the seed may not germinate because of the coldness and wetness of the soil. Or, if the plants come up and cold weather follows, they become stunted and many die from fungous diseases. Where boll weevils are plentiful, it is advisable to plant as early as good stand of healthy plants can be secured and kept. Where there are no boll weevils, planting may be later and good yields may be secured, provided weather conditions during the latter part of the season are favorable. Later plantings require less cultivation than early ones.

**Methods of Planting.**—In nearly all cases cotton is planted in drills with a one-horse planter, which opens a small furrow.



FIG. 57.—A good one-row cotton planter. (*Courtesy B. F. Avery and Sons.*)

drops the seeds, and covers them. Some planters drop bunches of seed in hills the desired distance apart. If the seed bed is in the proper condition and the planter is handled carefully, this is a very satisfactory way of planting. If planted in hills the right distance apart, cotton is more easily thinned properly. Frequently, good stands are ruined by careless thinning. A few farmers drop seed by hand; and a few use two-row drill planters. Planting by hand is not economical, and except where planting is done on the level, the two-row planters are not satisfactory. Beds vary so much in width and height that a two-row planter will not plant regularly.

Cotton is sometimes checked, or planted in hills, so that it may be plowed in two directions. This practice reduces the

necessary amount of hoeing to a minimum and makes it possible to control fairly easily troublesome weeds, such as coco grass (*Cyperus rotundus*). But the yield from checked cotton is not so great, as a rule, as from drilled cotton that is closely spaced and well cultivated.

A cotton planter, to be satisfactory, must be so constructed that it will drop seed regularly; that it will press the soil around the seed; and that it will plant the seed at a uniform depth. A planter with a small shovel to open a furrow, a roller behind to press the soil down on the seed, and a lever by means of which depth of planting can be regulated closely is the most satisfactory (see Fig. 57).

**Depth to Plant.**—The cotton plant is a native of warm regions, regions considerably warmer than the Cotton Belt during the spring, the time the young plants are getting a start. Being adapted to warmer regions, they are naturally weak and delicate in temperate climates. On account of their lack of strength, they cannot get out of the ground if planted very deeply or if the surface of the soil has a hard crust. Seed should never be placed deeper in the soil than is necessary for them to secure moisture sufficient for germination. A depth of an inch is sufficient usually, for rains are rather frequent over much of the Cotton Belt, frequent enough to keep the soil moist near the surface. "Barely cover the seed" is a rule followed by many. During periods of drought or in regions of light rainfall, seed, of course, must be planted considerably deeper.

**Quantity of Seed to Plant.**—It is the common practice to plant cotton seed at the rate of a bushel an acre. This is much more than would be needed if every seed would make a large plant. But they do not all make plants. Some fail to germinate, others germinate but the plants never get above the surface of the soil, and many others die of disease or are accidentally destroyed. To be sure of a good stand, it is necessary to plant a large quantity of seed and then thin out plants not wanted. More seed is needed on stiff clay land, or on old land low in organic matter where the soil tends to bake, than on sandy soil or on new lands. If a planter that drops seeds in hills is used, a smaller quantity can be planted with safety, but it is never advisable to use less than  $\frac{1}{2}$  a bushel per acre.

Planting seeds are sometimes delinted by running them through a machine that removes the linters, or a large part of the short

fibers and fuzz on the seed. If this is done, they pass through the planters more freely, plant more regularly, and germinate somewhat sooner if the soil is at all dry. Seeds may be delinted thoroughly by the use of strong acids, but this process is not practicable on a large scale.

**Vitality of Cotton Seed.**—There is much difference between varieties in respect to the length of time the seeds retain their vitality. As a rule, seed of big-boll varieties, especially varieties with large seeds, give a comparatively lower percentage of germination when the seeds are more than 1 year old. In some tests conducted by the writer with Cleveland and Triumph seed, less than 5 per cent of 3-year-old seed germinated. Seed from Trice and Simpkins, varieties with smaller bolls and seed, gave a high percentage of germination—85 or greater for 3-year-old seed. Express seed 7 years old showed a high percentage of viable seeds. Winters of North Carolina secured 90 per cent germination from seed 10 years old.

The use of seed more than 1 year old for field planting is sometimes advocated, and there are good reasons for doing this. Certain fungous organisms that cause diseases of mature plants are present in the seed, but will not retain their vitality more than 1 or 2 years at most. Plants coming from seed more than 2 years old will then be less subject to fungous diseases. There is still another reason for favoring old seed. Weaker seeds which would probably produce weaker and lower-yielding plants lose their vitality in a year or two and are thus eliminated.

Field tests made by Duggar failed to show any consistent gain in favor of the old seed. Tests made by the writer in the Mississippi Delta gave somewhat better yields for both 2- and 3-year-old seed. Apparently, old seed may be planted to an advantage, but planting should never be done until a germination test has been made.

**Cotton Spacing.**—The subject of cotton spacing, or the number of plants to be left to the acre, is of much importance to cotton growers, and it has received considerable attention from experimenters. Results obtained in different places have varied considerably, owing largely, no doubt, to the varying conditions under which the experiments were conducted.

**Width of Rows.**—The width of row now in use varies from 3 to 4 feet, but  $3\frac{1}{2}$  feet is the most popular (Table XXVIII). It is generally considered best to make the row width such as

will be most convenient for cultivation, and to regulate the number of plants to the acre by the spacing within the row.

**Distance in the Drill.**—The spacing of cotton plants is influenced by the prevalence of boll weevils more than by any other factor. The best distance for plants on a certain type of land before the weevils came is not necessarily the best distance now. Brown<sup>7</sup> made a review of all the more important cotton-spacing experiments carried on during the last 35 years. In his summary of the pre-boll-weevil experiments, he says:

In the sixty-four distance-in-the-drill-spacing experiments listed in the foregoing pages, the rows varied in width to some extent, and several different drill distances were used, some more often than others. The character of the soil and the climate varied in different places also. This makes an accurate summary or set of averages impossible, yet a survey of the results shows that 12-inch spacing, in  $3\frac{1}{2}$ - to 4-foot rows, was first in yield in twenty-four of the tests given. This was a distance used more often than any other, but it averaged best. Boll weevils did little or no damage in any of the experiments listed. On the less productive land the closer spacing gave better yields in the majority of cases. On the richer lands wide spacing gave best yields in a number of cases, but the results varied widely, owing probably to differences in rainfall, length of fruiting season, etc.

In his review of the experiments made under weevil conditions, Brown<sup>7</sup> says:

In the eleven different tests conducted, under moderate to heavy boll-weevil infestation, nine gave best yields for a spacing of 12 inches or closer. From this it seems fairly certain that, under heavy boll-weevil infestation, cotton should be spaced closely. The only question remaining to be decided is just how close it is to be spaced—how much closer than 12 inches. While leaving the rows unthinned gives the best yields in some cases, this practice is uncertain, and in no case will it be practicable on account of the difficulty in removing grass and weeds. There must be room between plants or between small clusters of plants for a hoe to work if grass and weeds are to be removed easily and effectively. This requires a space of 10 or 12 inches, and often more is taken. Hoes are 7 or 8 inches wide, and it is impossible to get a cotton chopper to hit within an inch of the place at which she is looking. Too often she is not looking at the row at all.

Prior to the coming of boll weevils, the fruiting season for cotton plants was long. Except in the northern edge of the Cotton Belt, there was time enough for plants to grow large, to bear

bolls to the outer end of later branches, and to utilize much space in the row. Under such conditions, especially on rich land, it was not essential that the plants be closely spaced in the row. They could grow large, utilize all the space in the row, and produce as good yields as, or possibly even better yields than if more plants were in the row. Under heavy weevil infestation the fruit must be set in a short space of time—a month or a little more. There is not much time for plants to make growth during the fruiting period; so they are still rather small when this period is over. This makes it necessary for plants to stand close together in the row if all space is used to the best advantage.

If weevil infestation is heavy, it is not practicable to leave plants close enough together in the row for maximum yields if only one plant is left in a hill. Leaving two or more plants in a hill a hoe's width apart obviates this difficulty. On poorer soils, better yields may be obtained usually if three or four stalks are left in a hill. On rich soil, one plant every 12 inches is sufficient.

Under ordinary plantation conditions cotton plants are rarely spaced close enough for best results. Lengthy skips are frequent, and hills are left too far apart by the choppers. The plants in the fields that the writer has seen will not average much closer than 2 feet.

**Effect of Spacing on Comparative Yield, First Picking.**—In the spacing experiments in which comparative yields from different pickings are recorded, the closely spaced plats yielded the highest percentage of their crop the first picking. Duggar,<sup>6</sup> in Alabama, secured results as follows: 42 per cent of the whole crop was obtained the first picking from plants spaced 12 inches; 38 per cent from plants spaced 18 inches; 30 per cent from plants spaced 24 inches; and 26 per cent from plants spaced 36 inches.

Close spacing is conducive to earlier maturity, or at least to more open bolls at an early date. If there are more plants on the ground, there is a higher percentage of primary bolls, or bolls springing directly from the main stalk, or from fruit branches on the main stalk. Bolls on these parts develop earlier than bolls on secondary branches, and if the percentage of these is higher, an earlier crop is produced.

**Number of Stalks to the Hill.**—Several tests have been made to determine whether or not there is an advantage in leaving more than one stalk of cotton in a hill. Balls and Holton,<sup>8</sup> in some careful tests with Egyptian cotton in Egypt, secured 10 per cent

greater yield regularly from two stalks in a hill as compared with one stalk. Each hill had 0.34 square meter space. This represented 12,000 hills to the acre.

Lee, in North Louisiana, secured better yields from two stalks in a hill at all distances except 8 inches, one stalk to the hill leading at this distance. Rast, in *Bulletin 115* of the Georgia College of Agriculture, says that in tests made in Georgia two stalks to the hill yielded more than one for all distances greater than 14 inches.

Ayres, in cultural experiments on rich bottom lands in Arkansas, secured best yields the first picking and also the best total yield, from two plants to the hill. His plants were spaced 18 inches in the row, the rows being 4 feet apart. Walker and Ayres, at the Mississippi Delta Experiment Station in 1919, secured better yields from two plants in a hill for 12, 16, 24, and 28 inches. With 8-inch spacing, one plant to the hill led two by a margin of 50 pounds of seed cotton per acre.

From the tests made it appears that for distances that are practicable for cultivation—12 inches or more—two plants to the hill will give better yields than one.

Redding,<sup>3</sup> of Georgia, has shown that the nearer the area allotted to each plant approaches a square the greater its yield will be, comparatively. Probably maximum yields are to be secured from one plant in a hill, but the difficulties in the way of cultivation when plants are spaced closely enough for best yields make this type of spacing unsatisfactory.

**Spacing for Different Varieties.**—But very little work has been done to determine the difference between different varieties in regard to space required for best yields. Duggar<sup>6</sup> found that Welborn, a cluster variety, gave its maximum yield when spaced 1 foot in the drill, while Peeler, a spreading variety, yielded best where the plants stood 2 feet apart in the row. Four-foot rows were used in both cases. In work carried on by Walker<sup>9</sup> at the Mississippi Delta Experiment Station, Trice, a dwarfish variety, gave its best yield when spaced at 6 inches. Lone Star and Columbia, larger-growing varieties with heavy foliage, yielded best at 12 and 18 inches, respectively. Results by Pittuck, of Texas, and others show no consistent differences. It looks reasonable, however, that a vigorous, rank-growing variety will be able to use to an advantage more space than a weaker, smaller-growing variety. With varieties with heavy foliage, crowding

the plants may result in much boll rot during a rainy season. The dense shade produced is favorable to fungous growth on the bolls.

**Single-stalk Cotton Culture.**—The essential feature of the single-stalk system of cotton culture is the suppression of vegetative branches by delaying thinning until the plants are 10 or 12 inches tall. When plants are allowed to crowd each other in the row for a time, the development of vegetative branches is prevented to some extent. It has been thought by some that the late thinning fosters the development of fruit branches on the lower part of the plant; that the plants having few vegetative branches fruit earlier; and that the crop yield is larger because more early plants can be grown on the same area.

It appears that the advocates of the single-stalk system have not distinguished between the effect of the delayed thinning and the effect of close spacing. Close spacing gives all the beneficial results claimed for the single-stalk system, and, as shown by the work of Ayres, of the Arkansas Experiment Station, McClelland, of Georgia, and Brown,<sup>7</sup> of Mississippi, cotton thinned at the regular time, when the plants are 3 to 5 inches tall, will yield more than cotton thinned late, provided the same number of plants is left in both cases. Delaying the thinning has a tendency to make plants tall and "whip-like," and hinders the development of fruit branches as well as vegetative. The bulk of experimental evidence indicates that cotton plants should be thinned as early as it is safe to do so; that is, as soon as the danger of losing a stand from cold weather, damping-off fungi, etc., has passed, and before the plants are stunted by undue crowding.

**Cultivation.**—Intertillage of cotton has for its purpose the destruction of weeds, the loosening of the soil so that it may be properly aerated, the production of a surface mulch that will retard the loss of water from the soil, and the placing of the soil in proper condition for plant nutrients to be rendered most available. Work by Cates<sup>1</sup> showed a close relationship between cotton yields and the number of cultivations the crop received. The average yield of 258 farmers who worked their cotton four or five times was 763 pounds of seed cotton, while the average yield of 171 farmers who cultivated six or seven times was 907 pounds, and the average of 20 farmers who cultivated eight or nine times was 1,012 pounds.

**Broadcast Tillage.**—Under certain conditions, broadcast tillage with a light harrow or weeder may be very helpful and economical. It may be used to break the crust after a rain, or to kill numerous young weeds. A hard crust may do much harm in preventing young plants from breaking through the soil. But it is only rarely that broadcast tillage can be used satisfactorily. Since cotton is usually planted on beds and covered very lightly, any harrowing that will tear up the crust satisfactorily is apt to tear up too many young plants or drag the seeds out of the row if they have not yet germinated.

The middles between the rows will not be cultivated to any extent unless the ridge is torn considerably. If there is much trash or litter in the soil, the harrow will catch it, drag it out, and tear up cotton plants; or if the stand of plants is poor, the harrow will destroy too many, especially in spots where there are none to spare.

**First Plowing of Rows.**—The purpose of the first plowing is to loosen the surface of the soil and to destroy weeds. If the land has been well plowed in the preparation of seed bed, it is not necessary to cultivate deeply; but if the soil has not been well plowed, or if heavy, packing rains have fallen, deep cultivation will be helpful. Deep cultivation will not injure the cotton plants while small. It is important to plow close to the plants, so that there will not be a wide strip left to be hoed; but care must be taken not to throw much dirt to the row, or the small plants will be covered. All that are covered are killed. It is thus necessary to use plows with small shovels, or fenders on plows with large shovels. A spring-tooth cultivator (Fig. 58) is satisfactory for shallow cultivation, while a side harrow, a Perry cultivator, or a heavy plow with small shovels is better for deep cultivation.

If fields become very weedy or grassy owing to continued wet weather which prevents plowing or to the prevalence of very troublesome weeds, such as coco or Bermuda grass (*Cynodon dactylon*), it may be necessary to use a scrape or turning plow. The use of these implements for barring off cotton rows is not a good practice ordinarily, but it is effective in the destruction of a heavy growth of weeds when nothing else will serve. Weeds must be kept down at all hazards. If the scrape or turning plow is held so that the side next to the row does not run deeply, but little harm will be done.

Probably slightly better work can be done with one-horse plows than with two-horse, but the use of two-horse plows is much more economical in so far as saving labor is concerned. The negro laborers prefer to work one mule, and since with one mule a family can easily cultivate as much cotton as they can pick, there seems to be no reason for using two. The survey made by Cates<sup>1</sup> showed that one-horse implements are used very generally in the cultivation of cotton in the United States.

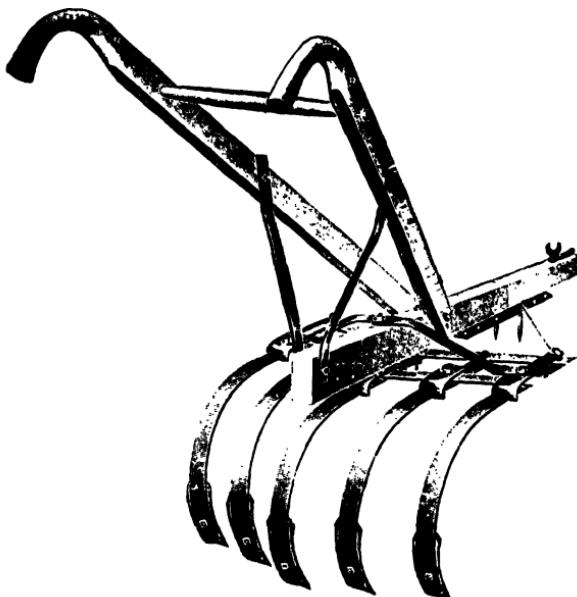


FIG. 58.—Spring-tooth cultivator. A good implement to use in plowing small cotton. (*Courtesy Molina-Hooper Company.*)

**Hoeing.**—The first hoeing that cotton receives is frequently spoken of as "chopping." The laborer scrapes, or scalps, all the land in the row left unplowed and takes out unnecessary plants, leaving two or more in hills or bunches the desired distance apart. A machine with revolving blades has been made to chop out cotton, but it is doubtful if it will come into general use. It is not satisfactory for use where stands are "skippy," or where the surface of the rows is not even. One or more later hoeings are given, the number being determined by the amount of weeds not destroyed by the plow. At the later hoeings the number of plants in a hill is commonly reduced to one, but better yields

would be secured if two were left. It seems to be a very common mistake for hoe hands to cut out too many plants when thinning cotton. They leave the hills too far apart, and usually but one tender plant in a hill. Many plants are destroyed accidentally in later hoeing. Careless plowing covers up a good many more, and if the season is unfavorable while the plants are small, many die from disease. The ultimate result is a poor stand. If more plants are left in the chopping process, the final stand is better and the yields greater.

Hoeing is expensive tillage, but apparently there is no way to avoid it. On account of the weakness of young cotton plants, it will always be necessary to plant an extra amount of seed to insure a good stand. There will then be plants to remove and this can be done only with hoes. Drilled cotton will yield more than checked cotton. If it is drilled, the weeds in the row can be removed only with hoes.

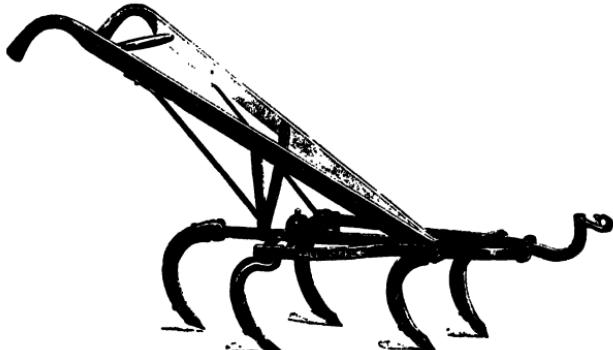


FIG. 59.—A five-shovel cultivator much used in cultivating cotton.

**Second and Subsequent Cultivations.**—The purpose of the second and later cultivations is similar to that of the first. If the row has been barred off at the first cultivation, it is essential that soil be thrown back to the row at the second. It is well, too, for a small amount of soil to be thrown to the row at each subsequent plowing until the plants are large enough to shade the ground in the row. This tends to keep down grass and weeds and to supply a mulch between plants. The second cultivation may be deep, but later ones should be shallow. It is very necessary, however, that all cultivations be deep enough to destroy grass and weeds, as the elimination of these is more important than anything else. Cultivators with three to five

medium-sized shovels are best for the second cultivation (Fig. 59). For later cultivations the same implements may be used, but the shovels should be replaced by small buzzard-wing sweeps (Fig. 60). A double shovel with two large sweeps or a two-horse cultivator with sweeps (Fig. 61) is satisfactory for later cultivations. In a few regions where intensive cultivation is not needed, as in some of the semiarid regions of Texas, two-row cultivators are used. Small turning plows or stocks with one large shovel are used in later cultivations by many small cotton farmers.

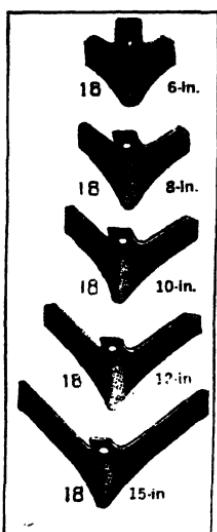
These may serve as makeshift tools where the land has not been well plowed in the preparation of seed bed, or where there is but one small mule to tend the crop—a mule too light to pull a heavy plow. These implements are not economical, and their use violates good cultural practices. They are to be classed as primitive implements.

It is considered good practice to stir the soil after every rain as soon as the ground is dry enough for working; or in case rains have not fallen, about once a week. It often happens that continued wet weather prevents plowing for days or even weeks; consequently, the number of cultivations is lessened. The ground should not be plowed while wet. Cultivation should be continued until plants are mature, or have put on a good crop of bolls. In regions where boll weevils

FIG. 60.—Sweeps used in cultivating cotton.

are numerous it is is advantageous to cultivate late in order to keep plants growing and blooming. As long as there are enough flower buds for the weevils, they will not attack young bolls seriously. In the central part of the Cotton Belt "laying by" takes place, or cultivations cease, about the first of August. Farther south the date is earlier.

**Depth of Cultivation.**—It is not possible to say just how deep cotton should be cultivated, but the following rule should serve as a guide. Cultivate as shallow as is consistent with the securing of the main objects of tillage, that is, just deep enough to form a suitable soil mulch and to destroy weeds. The first cultivation may be either deep, medium, or shallow without injury to the plant. If the seed bed has been well prepared



before planting, however, deep cultivation is not needed, nor is it desirable. Deep cultivation is never desirable when it can be avoided. Plants get only a limited amount of nutrients from the upper few inches of the soil which is stirred, because the roots are destroyed at each cultivation. Hence, the deeper the soil is stirred the deeper the plant roots must go to obtain nutrient materials and moisture. It is necessary that cultivation be

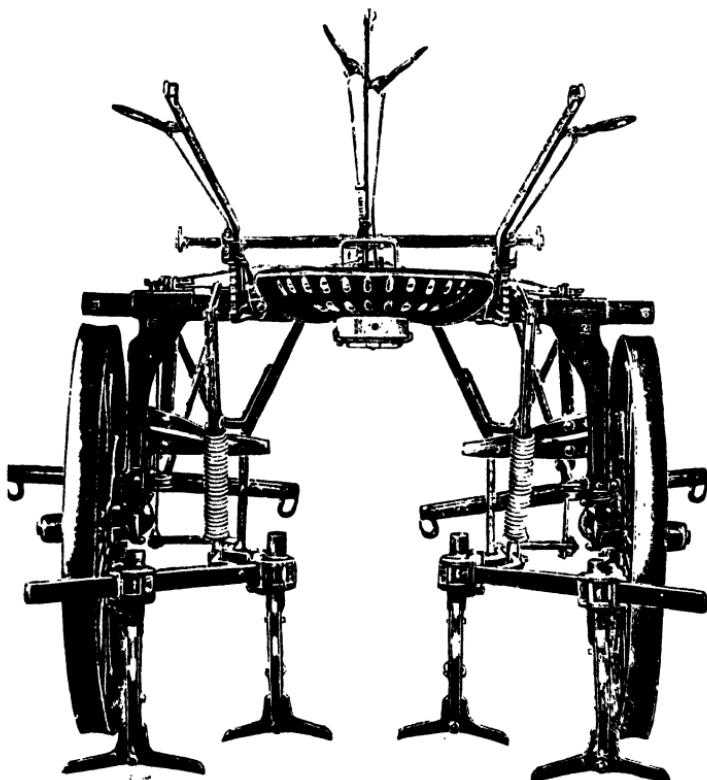


FIG. 61.—Planet Jr., pivot axle, two-horse riding cultivator properly equipped with sweeps for shallow cultivation of cotton.

deep enough to form a mulch that will check evaporation and to destroy vegetation. Under ordinary conditions  $1\frac{1}{2}$  to 2 inches is deep enough to meet the requirements of good tillage, though there are conditions which make deeper plowing necessary. If the mulch is formed from coarse-textured soil or is made up of small clods, cultivation must necessarily be deeper in order to accomplish its purpose. The finer the soil particles the thinner

the mulch may be made and still conserve the moisture. If, owing to unfavorable conditions, weeds and grass have become too large for shallow cultivation to be effective, then it is necessary to plow deeper. Shallow cultivation, except when adverse conditions demand that it be deep, is to be recommended for cotton.

**Topping Cotton.**—Some farmers practice cutting off the tip of the main stem, or the tip of the main stem and of the main branches, a few weeks before bolls begin opening. The theory is that the topping checks vegetative growth and increases fruiting, but it is very doubtful if this belief is well grounded. It is the general opinion among experimenters that, as a general rule, topping decreases yields. The results, however, seem to depend to some extent upon the weather conditions. Work done at the North Carolina Experiment Station indicates that topping may be profitable where the land is rich. Redding,<sup>3</sup> of the Georgia Station, makes the following statement: "As a rule, the operation of 'topping' does not pay. It oftener injures than benefits. It is not recommended." Results obtained by Ayres,<sup>4</sup> at the Delta Branch Station of Mississippi, showed a loss of 233 pounds of seed cotton per acre when topped 50 days after planting and 93 pounds when topped 60 days after planting.

**Cotton Culture in Arid Regions.**—As soon as the preceding crop is removed, the old stalks are cut and the ground plowed to a depth of 6 to 8 inches. It is left in this condition during the winter so as to absorb any rain which may fall. Irrigation may be applied at any time, since there is no danger of getting too much water in the soil, which should be wet to a depth of 4 or 5 feet before the cotton is planted. It is important that a good seed bed be prepared. Work and irrigation done during the winter usually save much labor and expense during the summer.

Planting is done from Apr. 1 to 20, with either a one-row or two-row planter, in rows 42 to 48 inches apart. The cotton is thinned to 8 to 14 inches in the drill, the distance depending on the soil. Cultivation does not differ much from cultivation in other sections. It should begin early and continue late, the primary objects being to keep down weeds and conserve moisture. It is always necessary to stir the soil after each irrigation. All cultivations are shallow, since the soils tend to dry as deeply as stirred.

It is not possible to say just when or how cotton should be irrigated, since this is determined by soil and climatic conditions. Water should be turned on when the plants show the need for it.

It is sometimes necessary to irrigate when the plants are very small, whereas in other cases it may be delayed for a time. Need of water is indicated by a wilting of the plants during the hot part of the day, especially when the wilting begins in the forenoon. The plants should not be allowed to suffer for water after blooming begins, for it is then that the plant needs its maximum supply. Irrigation should be continued until most of the bolls are mature; if it is not continued, the quality of the lint may be poor. Much care should be taken with late irrigation, since too much moisture may cause the bolls to rot.

**Cotton Culture in Foreign Countries.**—Cotton in Egypt is grown principally under irrigation and is cultivated by hand. A primitive plow is used in many instances for breaking the land and for making crude ridges. The land is usually broken two or three times. After the ridges are formed with the plow, the hoe is used for breaking the clods and completing the ridges. They are made about a month before time of planting. Ten to twenty seeds are planted in each hill. The hills are not placed on top of the ridge, but 3 inches down on the south side, so as to protect the seedling plant from the north wind. They are about 12 to 16 inches apart, and the rows 24 to 30 inches. The ground is dry when the seed is planted but is watered soon after. Planting is done in March or April. About 3 weeks after the cotton is planted it is hoed, the plants being thinned to one plant in a hill, the weeds destroyed, and the soil stirred. The fields are watered at this time, again a little later, and again about the end of May. Watering after May is governed by the supply, which is limited. The use of artificial fertilizer is not general.

Cotton culture in India, although it is now making rapid strides forward, is still very primitive. A large part of the work is done by hand. Cultural methods vary in different sections. In the Punjab, a large part of the cotton is grown under irrigation. Seed are sown by hand, either broadcast or in drills, between April and June. The land is plowed once before planting and the plow is run through the cotton 2 or 3 months after it is planted. Picking begins about the first of September. Cultivation in the United Provinces is about the same as in the Punjab. In the Bombay Presidency, cotton culture is probably further advanced than in any other part of India. Most of the land is plowed. Seed are planted in lines with drills, and rotations are being followed to some extent. Planting dates range from June to September. Practically no commercial fertilizer is used.

Cotton culture in China is intensive, although very primitive, most of the work being by hand. The planters are men of small holdings with not enough capital to buy artificial fertilizer or the better implements, were they available. All natural manures are used. Two-handled wooden plows pointed with iron or steel are used for plowing the land. A rather peculiar system of rotations is generally followed. In May, just before the wheat is ready to harvest, cotton seed is planted among the wheat stalks and covered with a light layer of soil. The wheat is cut about the end of May and the young cotton plants left standing. When they are about 6 inches high, the ground is hoed and the dirt pulled to their roots. The plants are left 7 to 8 inches apart. At intervals during the growing season weeds are removed from among the plants by hand. The rainfall is ample, although not always well distributed.

South America seems to be a land of great possibilities as a cotton-producing country, but it is lacking in development. Cultural methods in use in most parts are of the most primitive type. There is very little seed-bed preparation, as the fields are usually not plowed. It is a common practice to burn off the grass and rubbish and then drop the seed in holes made with hoes. Cultivation is practically all with hoes. Planting is from the middle of December to June 1, the time varying with the section. There are no large plantations. Small fields are cultivated by the different farmers. Agricultural machinery, fertilizers, and scientific rotations are hardly known.

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## CHAPTER XIV

### FUNGOUS, BACTERIAL, AND OTHER DISEASES OF COTTON

The damage to cotton plants caused by fungus and bacterial diseases results in an annual loss of millions of dollars in the value of the cotton crop. In the Cotton Belt of the United States, the annual loss is from twenty to thirty millions, or about 4 per cent of the value of the crop. The damage varies greatly with the locality and the season, usually being much greater during years of heavy rainfall. In certain areas the damage is so great that cotton cannot be grown profitably under common methods of procedure.

The cotton plant is a native of tropical and subtropical regions and is naturally adapted to a hot climate, but most of the commercial crop is grown in temperate regions with hot summer weather. The young plants are very tender and easily injured by cold weather. A temperature a few degrees below normal seems to lessen their resistance to diseases, making them much more susceptible to injury by fungi or bacteria. Plants under cultivation are usually much larger, but tender and more susceptible to disease than their wild relatives. Diseases, also, have much better chance to spread in cultivated fields, mainly because of the large number of plants growing near together.

The widespread and continued movements of modern trade and commerce serve to scatter cotton diseases, as well as many others, unless careful preventive measures are used. Cotton seeds are being moved freely from locality to locality, from state to state, and even from one country to another.

A certain amount of disease is to be found in any cotton field at any time, but in most instances the diseases are held in check by natural conditions. Wilt, anthracnose, angular leaf spot, and root knot are the most troublesome.

**Cotton Wilt** (*Fusarium rasinfectum*, Atk. (*Neocosmospora rasinfecta* (Atk.), Erw. F. Smith)).—Cotton wilt, a disease known also under the names of black heart and frenching, has long been

known by cotton growers. In the United States, it is to be met with in all the southern and eastern states, and is most prevalent in eastern South Carolina, southwestern Georgia, and southeastern Alabama (Fig. 62). New areas are being invaded each year. Many foreign countries also record the disease.

Cotton on sandy or sandy-loam soils is most commonly affected, but the disease is not unknown on clay and other soils. Probably all sandy soils of the Cotton Belt will be infected eventually. Gilbert<sup>1</sup> estimates that the annual loss in the United States due to cotton wilt is \$10,000,000. It is a difficult matter to estimate the exact damage, for many plants infected with wilt

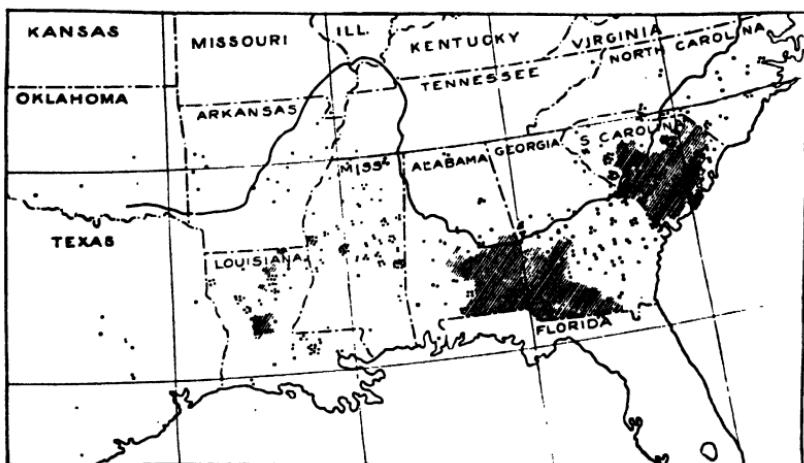


FIG. 62.—Map of the Southeastern states, showing the geographical distribution of cotton wilt in 1921. The shaded portions show where the wilt is general, while the dots indicate scattered localities where the disease is known to occur. (After Gilbert.)

show no external evidence, but their yield is necessarily reduced more or less. Other plants are stunted and their yield is reduced considerably, but they do not die outright.

The first external evidence of the wilt disease is usually a yellowing of the edges of the lower leaves and the area midway between the main ribs of the leaf. This yellowing spreads widely in the leaf, and the part first discolored soon turns brown and becomes shriveled and somewhat curled. The shriveled leaves later fall, leaving stem and branches nearly bare. Often the disease does not cause a shedding of leaves, but causes a stunting or dwarfing of the main stem of the plant. One or more of the lateral branches outgrows the main stem (Fig. 63). In some cases



FIG. 63.—Wilted cotton stalk cut across to show the blackening of the inside (A); cotton plant showing the main stalk stunted by wilt and one lower branch normally developed, only one side being infected (B). (After Gilbert.)



FIG. 64.—Cotton wilt; wilted plant on right, resistant plant on left. (After W. A. Orton, Bul. 333, Bur. Plant Industry, U. S. Department of Agriculture.)

all the leaves on an apparently healthy plant suddenly wilt and many fall (Fig. 64). If the interior of the stem, root, or even the petioles or leaf blades (in later stages) of a wilt-diseased plant be examined, the woody parts are seen to be brown or darkened (Fig. 63A). This is the best diagnostic symptom. No other disease discolors these parts of the plant in this way.

Atkinson<sup>2</sup> observed cotton seedlings growing on the black-belt soils of Alabama with indications of wilt when but a few days old. Ordinarily, the disease does not do much damage until the plants are about a foot high. In cases of light infection the plants in many instances attain full size.

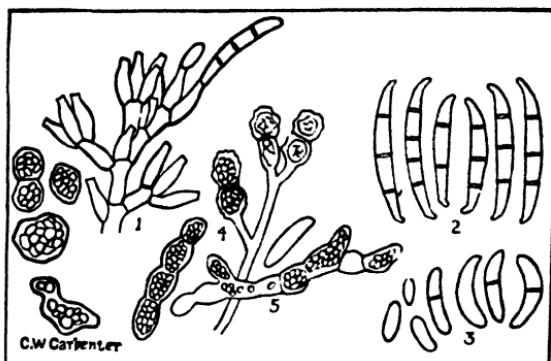


FIG. 65.—The cotton wilt fungus (*Fusarium vasinfectum* Atk.): 1, Conidiophore; 2, macroconidia; 3, microconidia; 4, chlamydospores; 5, bits of swollen hyphae. (After Gilbert.)

**The Causal Organism.**—The cotton-wilt disease was first identified and the causal fungus described by Prof. G. F. Atkinson,<sup>3</sup> in Alabama, in 1891. The fungus, *Fusarium vasinfectum*, Atk. (*Neocosmospora vasinfecta* (Atk.), Erw. F. Smith), has hyphae 2 to  $4\mu$  in diameter and yellowish at maturity; conidia are born singly; microconidia, oval, continuous; macroconidia, falcate, two to three septate, 1 to 2 by 2 to  $4\mu$ . Ascigerous stage has not been identified with a certainty. Chlamydospores are also formed (Fig. 65). Fungus lives saprophytically in soil once infected and enters cotton plants through the roots. Inside the plants the hyphae grow freely throughout the vessels and water-carrying ducts, later plugging them with mycelium so that they cannot function.

The organism causing okra wilt is thought to be identical with the one just described, but the one causing wilt of cowpea, ginseng,

watermelon, and other cucurbits, while apparently identical morphologically, will not infect cotton.

After soil is once infected, the wilt-producing organism may live in it saprophytically for years, and spread to some extent by natural growth. If susceptible varieties of cotton are grown on the soil, spread by natural growth is more rapid. There are numerous ways whereby uninfected soil may become infected if near soil contains the wilt organism; as, for instance, by the transference of soil from one field to another on plows and other implements and on the feet of men and animals, by water during floods, and by infected manure that is hauled out and spread on the farm. There is no reliable evidence that infection is carried by cotton seed.

*Control Measures.*—Aside from being more troublesome during wet seasons, or rainy spells, cotton wilt seems to be little affected by climatic conditions. A number of different control measures have been tried, but few have been found worth while. Late planting is ineffective. Various soil fungicides have been applied in amounts much heavier than would be practicable to use in farming operations, with virtually no benefit. Commercial fertilizers are likewise ineffective. Neither kainit, acid phosphate, salt, lime, potash, nitrate of soda, nor any other fertilizer that has been tried gives satisfactory results. These have been used alone and in various combinations.

Stable manure has been found to be of some help on land that is not heavily infected. The manure probably does not affect the fungus, but does stimulate the plants to better growth and thus increases their resistance. Fulton<sup>4</sup> reported a loss twice as great from unmanured plots as from plots that received thirty loads of manure per acre. The disease also spreads more rapidly in the unfertilized plots. Plowing under cowpeas and other leguminous crops had a similar, though less marked, beneficial effect. The writer has secured considerable benefit from the use of nitrate of soda or barn manure on wilt-infected soil at the Mississippi Experiment Station, but the wilt there was not severe.

The burning of diseased plants has been recommended by some as a control measure. This is hardly worth while except to retard the spread of the disease when it is just starting in a new area. Robbing the soil of the much-needed organic matter that

would come from the decay of the cotton stalks is a weighty reason for not burning them.

Since the wilt fungus can live in the soil saprophytically for a number of years, it is a difficult matter to eradicate it by crop rotation. Short rotations do no good. Keeping cotton off the land 8 or 10 years has been found to lessen the soil infection, but does not eradicate the organism altogether. Since root knot caused by nematodes commonly occurs with wilt and increases its severity, rotations may be helpful. Nematodes may be so reduced that susceptible crops can then be grown profitably by growing, for 2 or 3 years, crops immune to nematode attack.

For wilty soil infected with nematodes, Cauthen<sup>b</sup> recommends the following rotation for Alabama:

*First Year.*—Plant corn and between the corn rows or hills plant Iron or Brabham cowpeas. Where early autumn pasture for cattle is desired, velvet beans may be planted with the corn and grazed while green and in time to sow a fall grain crop.

*Second Year.*—Plant oats; after the grain is cut for hay or seed, plant the stubble in Iron or Brabham cowpeas for hay or seed. Follow this with some winter grain for a cover crop.

*Third Year.*—In the spring, plow under the cover crop and plant some wilt-resistant variety of cotton.

**Wilt-resistant Varieties.**—For fields heavily infected with cotton wilt, the only control measure of much value is the use of wilt-resistant varieties. Different varieties, and even plants of the same variety, differ greatly in their resistance. Some are nearly immune, while others are very susceptible. By selecting, for a series of years, immune plants in fields where the disease was prevalent, it has been possible to develop certain valuable wilt-resistant varieties (Figs. 66 and 67).

The first wilt-resistant variety developed was Dillon. This came from some selections made in a badly wilt-infected field of Jackson Limbless cotton growing near Dillon, S. C., in 1900. Selections were made by a representative of the U. S. Department of Agriculture. The strain isolated proved to be resistant to wilt and nematodes, and has continued to be one of the most resistant of varieties; but it is objectionable on account of its cluster habit, late maturity, and bad picking qualities.

On rich soil, plants belonging to the Dillon variety grow tall with two or three long vegetative branches originating near the

base of the plant; fruit limbs very short; bolls in clusters, small, slender, somewhat pointed, and difficult to pick; seed small and fuzzy; lint,  $\frac{7}{8}$  inch; lint per cent, 37 to 38.

Other wilt-resistant varieties of merit are Dixie, Modelia, Lewis-63, De Soto, Dix-Afifi, Tri-Cook, Covington-Toole, Council-Toole, Cook-307-6, and Wood. Some other new strains, such as Dixie-Triumph and Dixie-Cook hybrids, now being tested by the U. S. Department of Agriculture, and various hybrids and selections made by different experiment stations, give promise of



FIG. 66.—Typical plant of Dixie wilt-resistant cotton. (After Gilbert.)

being good, but they have not been tested sufficiently to determine their relative values. The leading varieties are described briefly in the following paragraphs.

*Dixie*.—Developed by Orton of the U. S. Department of Agriculture from an individual plant selection made at Troy, Ala., in 1902 (Fig. 66). It was thought to be a natural hybrid between certain Upland varieties being grown there on wilt-infected land. The plant is vigorous, wilt-resistant, of medium height, pyramidal, nearly of the Peterkin type; usually with two or more large basal

branches with long, slender, slightly dropping fruit limbs; bolls medium size, about seventy-five being required for 1 pound of seed cotton, easy to pick, but very stormproof; seed small, weight of 100 seed being 10 grams; variable in color, but typically covered with greenish-brown fuzz; lint, about  $\frac{7}{8}$  of an inch; percentage of lint to seed, 34 to 35.

*Modella*.—Developed in Georgia some years ago by A. C. Lewis, of the State Board of Entomology; selected from Excelsior; Peterkin type or near it; plants of medium size, with straight fruit limbs and three or four basal vegetative branches; bolls



FIG. 67.—Dixie cotton on left; on right native green seed. Shows great difference in resistance to wilt disease. (After Lewis.)

rather small, eighty to ninety-five to a pound of seed cotton; lacking in storm resistance; seed small, many smooth; lint,  $\frac{3}{4}$  to  $\frac{7}{8}$  inch; percentage of lint, about 35; late variety.

*Dix-Afifi*.—Originated in Georgia recently by A. C. Lewis; hybrid between Mit-Afifi, an Egyptian variety, and Dixie; plants resemble Dixie; bolls of medium size, easy to pick, but late in maturing; lint,  $1\frac{3}{16}$  inches; percentage of lint, 30 to 32.

*Lewis-63*.—A hybrid originated in Georgia by A. C. Lewis; plants of Peterkin type; bolls of medium size, storm-resistant; lint, 1 inch; percentage of lint, 32 to 36; medium early and one of the best wilt-resistant varieties yet produced for growing where boll weevils are troublesome.

*Council-Toole*.—Originated from a plant selection made by A. C. Lewis, of Georgia; plants of Peterkin type; bolls rather small; lint, 1 inch; percentage of lint, about 35; one of the two leading varieties grown in Georgia.

*De Soto*.—Originated from plant selection made by A. C. Lewis, of Georgia; very similar to Council-Toole described above.

*Covington-Toole*.—Originated in 1910 by W. F. Covington, Headland, Ala.; selection from Toole; Peterkin type; bolls rather small; lint,  $\frac{7}{8}$  inch; percentage of lint, 35 to 38; rather late for growing in regions of heavy weevil infestation.

*Tri-Cook*.—Originated in 1910 by M. R. Hall, James, Ala., from a mixed lot of Cook and Triumph plants; thought to be a hybrid between those varieties; plants of the big-boll type, resembling Cook rather closely; boll of medium size and rounded; lint, 1 inch; percentage of lint, 34 to 40. This variety is not uniform, but ranks well in wilt resistance and in yield when grown in weevil-infested regions.

*Cook-307-6*.—Originated by the Alabama Experiment Station in 1909; selection from Cook; big-boll type, resembling Cook rather closely; lint,  $\frac{7}{8}$  inch; percentage of lint, 34 to 40. This variety possesses considerable resistance to wilt and boll rot, but does not yield well where boll weevils are numerous.

*Wood*.—Developed by Judge Sam Wood, of Abbeville, Ala. Cauthen<sup>5</sup> describes this variety as follows:

Its plants are tall and semicluster in habit. It is not easy to pick, has medium-size bolls, matures late, and has heavy foliage, but it shows considerable wilt resistance and is productive. The seed are of medium size and fuzzy; its fiber is short; it turns out about 35 per cent lint.

*Rivers and Centreville* are two varieties of Sea Island cotton that are reputed to possess some wilt resistance.

**General Characteristics of Wilt-resistant Varieties.**—Most of the wilt-resistant varieties that have been developed belong to the Peterkin type, with tall, vigorous-growing plants. The resistant Cook selections are marked exceptions to the general rule.

The extra-early varieties like King, Simpkins, and Trice are very susceptible to wilt. Cleveland and certain strains of Cook are more or less wilt-resistant, but several other of the big-boll varieties, as, for instance, Lone Star and Russell, are very susceptible. Most Sea Island varieties are susceptible, but Egyptian

TABLE XXIX.—STUDY OF WILT RESISTANCE, MISSISSIPPI EXPERIMENT STATION, 1917

Variety	Pounds of seed cot-		Pounds of lint per		Per cent of seed cot-		Length of staple, in		Value of staple, in		Value of lint per		pound, in cents per		Total money value per acre		Per cent of plants infected and slightly damaged		Per cent of plants killed or badly injured		Rank in money value	
	ton	ton	ton	ton	cent	cent	cent	cent	cent	cent	cent	cent	cent	cent	cent	cent	cent	cent	cent	cent	cent	cent
Trice <sup>a</sup>	612	29.9	182.9	Good	1 1/16	full	33 1/2	\$ 61.27	\$15.05	\$ 76.32	3.2	16.5	80.3	11								
Improved Dixie	837	30.2	252.7	Good	1	31	78.33	20.47	98.85	55.7	15.4	28.9	8									
Wannamaker-Cleveland <sup>b</sup>	906	35.6	322.5	Good	1	full	31 1/2	101.58	20.44	122.02	37.3	30.8	31.9	3								
Tri-Cook	1,030	33.8	348.1	Good	1	31	107.91	23.87	131.78	67.1	24.6	12.3	1									
Cook-307-6	767	33.6	257.7	Fair	7/8	30	77.31	17.85	95.16	63.2	31.9	4.9	9									
Express-350 <sup>c</sup>	782	28	218.9	Good	1 1/16	39	85.37	19.79	105.16	26.7	20.0	53.3	6									
Dix-Afifi	767	29.9	229.3	Fair	1 3/16	38 1/2	88.28	18.83	107.11	79.2	13.3	7.5	5									
Lewis-63	1,030	32.9	338.8	Fair	1	30 1/2	103.33	24.22	127.55	88.7	4.6	6.7	2									
Covington-Toole	713	34.3	244.5	Fair	7/8	30	73.35	16.41	89.76	81.5	8.8	9.7	10									
Council-Toole	844	29.9	252.3	Good	1	31	78.21	20.72	98.93	77.6	12.5	9.9	7									
De Soto	937	29.9	280.1	Fair	1	30 1/2	85.43	22.99	108.42	76.8	12.3	10.9	4									

<sup>a</sup> Susceptible.<sup>b</sup> Somewhat resistant.

varieties, when grown in the United States, appear to possess some resistance.

No variety of cotton is resistant to wilt if the soil is infested with nematodes, which cause the root-knot disease of cotton. The wilt fungus enters wounds in the roots made by the nematode worms. Before cotton can be grown successfully on such land, it is necessary to eradicate the worms or reduce the nematode infestation by growing for two or more years other crops that are immune or resistant to the nematodes.

As has been shown, different varieties of cotton differ considerably in their ability to resist the wilt disease. Brown and Aines<sup>6</sup> found by cutting into the stems and roots of cotton plants late in the season that a large percentage of the plants of all varieties, resistant as well as non-resistant, were infected (Table XXIX). Although infected, the resistant varieties were able, in most cases, to withstand the attack and gave no external evidence of disease.

Cauthen,<sup>5</sup> in his experiments with wilt-resistant varieties of cotton grown at a number of different places in Alabama, had from none to 82.5 per cent of his plants die, the percentage depending on the variety and the location (Table XXX).

TABLE XXX.—PERCENTAGE OF PLANTS DEAD OR NEARLY DEAD UP TO THE LAST COUNT OF THE SEASON

Location in Alabama	Year	Name of varieties tested									
		Dillon	Modella	Cook (check)	Wood	Covington- Toole	Tri-Cook	Cook-307 <sup>6</sup>	Cook (check)	Dixie	Dix-Affin
Loachapoka	1911	1.4	2.9	22.1	10.5	5.2	6.0	3.7	15.1	3.7	
Loachapoka	1912	3.0	28.0	35.2	17.2	25.1	12.9	12.4	39.4	4.9	
Brundidge	1912	3.7	10.2	68.2	11.6	10.8	6.6	10.2	33.7	3.2	
Liverpool	1913	7.4	29.2	68.0	27.5	9.6	19.0	28.4			
Notasulga	1913	3.5	21.3	43.9	19.5	7.4	12.0	14.3		18.7	
Tuskegee	1913	3.0	6.2	43.5	7.7	3.5	5.2	5.1	24.5	2.9	
Brundidge	1913	15.5	35.4	56.3	20.1	34.8	9.5	10.1	33.2	20.0	
Auburn	1914	....	7.0	21.6	14.6	4.6	0.9	6.1	3.0	2.7	
Notasulga	1914	....	13.8	42.4	14.4	4.9	2.4	1.2	46.5	14.1	
Liverpool	1914	....	1.6	8.0	1.4	1.1	0.6	0 0	4.9	7.7	0 0
Brundidge	1914	....	34.3	82.5	21.8	8.6	12.5	10.2	71.2	26.1	
Lowndesboro	1914	....	2.9	53.3	11.1	7.6	3.5	5.4	15.1	6.8	0 0
Notasulga	1914	....	10.1	45.2	21.5	16.8	7.0	10.4	26.6	4.5	
Notasulga	1915	....	14.8	3.0	8.3	6.3	10.1	1.8	46.5	1.2	
Notasulga	1915	....	9.8	18.9	13.2	15.7	3.7	16.3	18.9	7.1	
Greenville	1915	....	8.3	33.1	20.5	5.4	4.8	13.5	29.9	3.9	
Average percentage of loss			5.4	14.7	40.3	15.1	10.5	7.3	9.3	29.2	8.5

TABLE XXXI.—VARIETY TESTS, AMERICUS, GA.

Variety	1914			1915			1916		
	Pounds seed cotton per acre	Per cent healthy lint	Per cent healthy stalks	Rank in yield lint	Pounds seed cotton per acre	Per cent healthy stalks	Rank in yield lint	Pounds seed cotton per acre	Per cent healthy stalks
Improved Dixie.....	1,326	37	96	2	2,030	36	96	2	1,080
Lewis-63.....	1,326	37.5	96	1	2,100	36.5	96	1	891
De Soto.....	1,309	35	95	3	1,960	35	94	5	891
Council-Toole.....	.....	.....	.....	.....	1,925	37	95	3	945
Modella.....	.....	.....	.....	.....	1,925	36	94	4	837
King.....	374	36	10	6	665	35.5	20	12	324
Bank Account.....	.....	.....	.....	.....	.....	.....	.....	.....	216
Simpkins.....	.....	.....	.....	.....	.....	.....	.....	.....	324
Triumph.....	.....	.....	.....	.....	.....	.....	.....	.....	486
Half and Half.....	612	40	18	5	350	39	10	13	567
Cook.....	680	38.5	15	4	1,050	38	83	11	915
Cleveland.....	.....	.....	.....	.....	.....	.....	.....	.....	378
Dix-Aff.....	.....	.....	.....	.....	1,925	31	95	9	1,215
Express.....	.....	.....	.....	.....	1,750	30	85	10	756
Curtis Long-staple.....	.....	.....	.....	.....	.....	.....	.....	.....	234
Webber.....	374	32.5	10	7	840	30	24	14	1,200
Toole.....	.....	.....	.....	.....	1,820	36.5	80	6	675
Pulnott.....	.....	.....	.....	.....	1,750	37	80	7	1,215
Cook Alabama-307.....	.....	.....	.....	.....	1,645	37.5	90	8	437

TABLE XXXII.—VALUE OF SEED AND LINT PER ACRE OF WILT-RESISTANT VARIETIES IN ALABAMA

Location	Year	Dillon	Modella	Cook (check)	Wood	Covington- Toole	Tri- Cook	Cook- 307-6 (check)	Cook	Dixie	Dix- Aff
Loachapoka	1911	\$60.75	\$39.20	\$38.50	\$46.42	\$47.96	\$57.02	\$53.57	\$46.13	\$38.33	
Loachapoka	1912	30.42	25.24	28.18	39.15	36.63	41.68	45.03	28.18	35.35	
Brundidge	1912	52.74	35.56	20.14	38.54	50.27	46.56	41.94	39.54	44.42	
Notasulga	1913	54.40	46.10	43.29	56.21	58.86	66.25	42.72	....	47.20	
Tuskegee	1913	54.50	41.54	14.74	33.34	50.57	24.95	45.26	43.51	55.96	
Brundidge	1913	34.54	27.79	6.81	29.14	27.28	39.16	22.92	8.82	30.10	
Auburn	1914	12.94	13.89	16.07	21.13	19.32	14.72	15.99	14.64		
Notasulga	1914	....	....	22.46	23.63	18.97	26.73	40.25			
Liverpool	1914	....	29.68	29.25	30.44	35.90	29.00	30.54	28.08	31.56	\$29.07
Brundidge	1914	20.64	13.03	34.41	29.94	31.49	36.36	14.24	29.31		
Lowndesboro	1914	55.50	40.87	55.80	57.90	70.33	58.31	47.43	39.90	39.58	
Notasulga	1914	14.89	9.60	19.36	14.99	18.81	20.13	14.98	14.83		
Notasulga	1915	20.40	31.34	29.31	29.18	40.68	18.39	37.73	38.39		
Notasulga	1915	24.50	33.66	27.53	18.45	42.38	26.39	33.66	28.82		
Greenville	1915	11.43	20.96	16.94	18.30	22.67	15.98	20.25	16.32		
Average acre value of each variety	....	28.96	24.45	33.09	34.42	40.53	34.17	29.12	33.22		
Percentage of increase in acre value over average of checks	....	8.1	....	23.5	28.5	51.3	27.6	....	24.0		

Lewis and McLendon<sup>8</sup> report from 5 to 96 per cent healthy, resistant plants in their variety tests at Americus, Ga. These figures were probably based on the condition of plants as determined from external appearance (Table XXXI).

**Yields of Wilt-resistant Varieties.**—Under favorable conditions, wilt-resistant varieties yield comparatively well, a bale to the acre being not uncommon on productive land. On land infected with wilt, they yield considerably more than non-resistant varieties, provided they are not hindered by boll weevils, and are allowed sufficient fruiting period to produce a full crop. Cauthen<sup>5</sup> in Table XXXII, gives the comparative values of the products of resistant and certain non-resistant varieties when grown in Alabama on infected soil, from 1911 to 1915. Boll weevils were not present.

Lewis and McLendon<sup>8</sup> find that, as a rule, resistant varieties yield better than non-resistant when grown on infected Georgia soils, in the absence of boll weevils (Table XXXI).

TABLE XXXIII.—STUDY OF WILT RESISTANCE, MISSISSIPPI EXPERIMENT STATION, 1919

Variety	Pounds of seed cotton per plat	Pounds of seed cotton per acre	Lint, per cent	Pounds of lint per acre	Length of lint, inches	Value of lint per pound, in cents	Value of seed at \$75 a ton	Value of lint	Total money value	Rank in money value
Tri-Cook.....	22.50	703.134.3241.2	15 $\frac{1}{16}$	41 $\frac{1}{2}$	17.32	100.10	117.42			7
Cook-1110.....	20.75	648.439.4255.5	7 $\frac{1}{8}$	41	14.73	104.75	119.48			5
Wannamaker-Cleveland.....	20.75	648.434.6224.3	7 $\frac{1}{8}$	41	15.90	91.96	107.86			10
Council-Toole.....	26.50	828.131.7262.5	15 $\frac{1}{16}$	41 $\frac{1}{2}$	21.21	108.94	130.15			2
Express-432.....	22.00	687.531.0213.1	1 1 $\frac{1}{8}$	50	17.79	106.55	124.34			3
Dix-Afifi.....	19.75	617.226.0160.5	1 3 $\frac{1}{16}$	60	17.13	96.30	113.43			8
Express-350-64.....	27.25	851.526.9229.0	1 3 $\frac{1}{8}$ <sup>a</sup>	55	23.34	125.95	149.29			1
Cleveland $\times$ Covington-Toole.....	25.00	781.230.2235.9	15 $\frac{1}{16}$	41 $\frac{1}{2}$	20.45	97.90	118.35			6
Lewis-63.....	25.75	804.729.6238.2	15 $\frac{1}{16}$	41 $\frac{1}{2}$	21.24	98.85	120.09			4
Improved Dixie.....	12.75	398.434.1135.8	7 $\frac{1}{8}$	41	9.85	55.68	65.63			13
Express $\times$ Covington-Toole.....	21.75	679.730.6208.0	1 3 $\frac{1}{16}$	45	17.69	93.60	111.20			9
Covington-Toole.....	16.00	500.032.4162.0	15 $\frac{1}{16}$	41 $\frac{1}{2}$	12.68	67.23	79.91			12
Trice (Arkansas Station).....	22.75	710.928.4201.9	15 $\frac{1}{16}$	41 $\frac{1}{2}$	19.09	83.79	102.88			11

<sup>a</sup> Full.

Brown and Ames,<sup>6</sup> in Table XXIX, give comparative yields of resistant and non-resistant varieties grown in east central Mississippi on soil with moderate wilt infection and medium-

heavy weevil infestation. The wilt-resistant varieties led in yields under conditions prevailing.

In Table XXXIII, Brown and Anders<sup>7</sup> show yields under heavy boll-weevil infestation. The soil was the same as that used in the previous experiment (Brown and Ames<sup>6</sup>). In the latter experiment an early variety, Express-350-64, made a better yield than any of the wilt-resistant varieties. Similar results were secured other years when weevil infestation was heavy.

An earlier wilt-resistant variety of cotton is needed. The ones grown at the present time are too late to be profitable if weevil infestation is heavy.

**Root Knot of Cotton** (*Heterodera radicicola* (Greef), Muell).—Root knot is caused by a nematode, a small eel-like worm that enters the roots of cotton plants, multiplies greatly, and causes swellings or galls; later the nematodes go into a resting condition in a thick-walled cyst. This disease is to be found in most areas where cotton wilt prevails, being prevalent on the sandy coastal plain from Virginia to Texas. Although root knot may be met with in different soils, it is rarely found in any but light, sandy soils. Root knot troubles with certain crops have been reported from almost all countries of the world. Probably few cotton-growing regions are free from the disease.

Root knot is second in importance to wilt in damage done to the cotton crop. Gilbert estimates the average annual loss to the Cotton Belt in the United States to be around 200,000 bales of cotton and 100,000 tons of seed, a total loss of \$16,480,000 at prevailing prices (Dec. 2, 1920). A further loss is attributable to the disease as cotton plants are more susceptible to wilt if infected with nematodes.

*Symptoms of Root Knot.*—This disease can be identified most easily by examining the roots. If they show numerous more or less irregular knots or swellings ranging from the size of a pin head to  $\frac{1}{2}$  inch in diameter, root knot may be suspected (Fig. 68). If the interior of the knots is examined, small pearly-white, rounded bodies about the size of a mustard seed may be seen. These are the female nematodes (Fig. 69A). A microscopic examination is necessary to show the presence of the male worms. They are very slender, narrowed toward either extremity, and about 1 to  $1\frac{1}{2}$  millimeters in length (Fig. 69B).

Nematode-infected plants usually appear dwarfed or stunted, and are a pale, yellowish-green color. During hot, dry weather,



FIG. 68.—Root system of a cotton plant severely attacked by root-knot. (After Gilbert.)

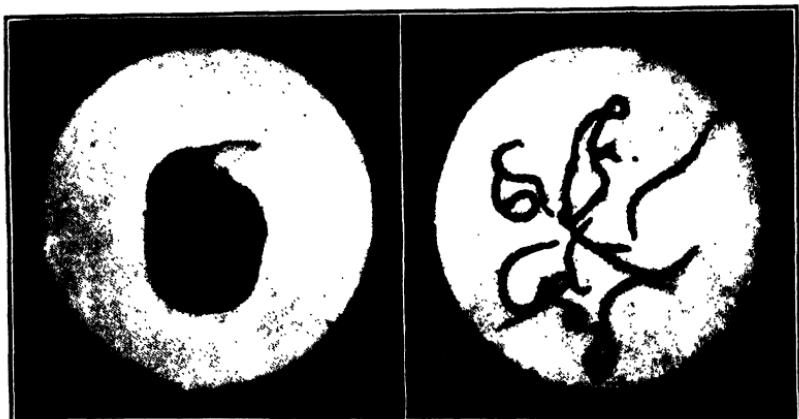


FIG. 69.—Adult female nematode full of eggs (A); young male and female nematodes (B) (both illustrations greatly enlarged). (After Gilbert.)

or even when there is sufficient moisture in the soil, infected plants tend to wilt more than normal ones do. If all the plants in the field are diseased, their abnormal appearance, as described above, may not be observed. Mild attacks are often unnoticed, but severe attacks may kill practically all the plants in the field.

*Life History of the Causal Organism.*—Hatching from an ellipsoidal egg, 67 to  $128\mu$  by 30 to  $52\mu$ , according to Bessey,<sup>16</sup> is a slender, cylindrical larva 375 to 500 $\mu$  in length and about 12 to 15 $\mu$  in diameter. The larva moves through the soil with considerable activity, and, although making no growth, may remain alive in the soil for several months. On finding a suitable root it seeks the growing point and enters, boring its way in by the aid of a spear-like tongue. Once inside the root, the young nematode ceases its activity and begins to enlarge and to absorb nourishment from the root. The presence of the worm in or among the cells of the root of the plant stimulates them to active multiplication, and there is produced the abnormal growth known as a gall, or root knot. It requires about 4 weeks for the female to reach full development and begin laying eggs. It is then flask-shaped, 400 to 1,300 $\mu$  in length and 270 to 500 $\mu$  in diameter (Fig. 69). Five hundred or more eggs are produced by one female. The larvae produced by these drill their way out of the eggs, in some cases even before the eggs leave the mother's body.

From external appearance, the larvae that produce males cannot be distinguished from the ones that produce females when they enter the plant roots. Inside the root they enlarge a little; later there is developed inside the old skin a slender, much elongated worm having the same general shape of the larva. This is the adult male (Fig. 69). It is 1,200 to 1,500 $\mu$  in length and 30 to 36 $\mu$  in thickness. After reaching the adult form the elongated male breaks out of the old skin, and moves through the tissues of the plant root in search of a female. The adult male probably takes but little food, and after meeting a female soon dies.

*Control Measures.*—Uninfected soil may become infected in various ways. Through their own activity nematodes travel through the soil a few feet in the course of a year. Bessey<sup>16</sup> estimates that the movement may be as much as 6 feet. The transference of infected soil from one field to another by the feet of animals or men, on plows, or on other farming implements serves to spread the disease. The flow of drainage water is

another means. The introduction of the disease into new localities is very often brought about by the use of infected nursery stock, cabbage, tomato, strawberry plants, etc.

Root-knot nematodes have been found attacking more than 400 different species of plants. This list includes many of our leading cultivated plants, as well as several species of weeds. On the other hand, there are several important cultivated crops that are not attacked by nematodes. This makes it possible to control them fairly easily by planning rotations in which resistant crops are grown 2 years in succession in a 3- or 4-year rotation. Corn, wheat, rye, oats, sorghum, most grasses, velvet beans, Brabham cowpeas, Iron cowpeas, and peanuts are immune or nearly so, and may be used in rotation with cotton.

Various chemicals, such as sulphur, formaldehyde, carbon bisulphide, calcium carbide, potassium sulphocarbonate, and ammonium sulphate, have been applied to the soil in the effort to eradicate nematodes. Some of these were found to be effective if applied in sufficient quantity, but were not of practical value for field use. Chemical fertilizers which will stimulate plants to increased growth and vigor may be helpful as a control measure. The plants may be able to make satisfactory growth in spite of the influence of the parasites.

**Cotton Anthracnose** (*Glomerella gossypii* (South.), Edg. (*Colletotrichum gossypii*, South.)).—Cotton anthracnose, or pink boll rot, has probably been present in cotton fields for many years. The disease was first described by Miss E. A. Southworth,<sup>9</sup> of the U. S. Department of Agriculture, in 1890, and the causal organism named *Cottetotrichum gossypii*. Atkinson,<sup>10</sup> of Alabama, working independently, published a paper in 1891 in which he verified Miss Southworth's work. Edgerton,<sup>11</sup> of Louisiana, discovered what he interpreted to be the perfect stage in 1909 and proposed the name *Glomerella gossypii* (South.), Edgerton. Edgerton's discovery has not been verified except in that Shear of the U. S. Department of Agriculture obtained the perfect stage of the fungus in pure culture. Barre,<sup>12</sup> of South Carolina, has contributed much to our knowledge of the disease, especially of the growth of the causal organism in cotton bolls and seed, and of control measures.

Cotton anthracnose is probably widespread in most of the cotton-growing regions of the world. Edgerton<sup>13</sup> mentions it as being reported from Trinidad, British Guiana, West Indies, and

possibly India and Natal. In the United States it has been reported in all of the cotton-growing states except California, Arizona, and New Mexico.

The annual loss due to cotton anthracnose amounts to millions of dollars. It causes damage by killing young seedling plants before they get above ground or soon after, thus making stands poor. It also causes many bolls to rot, ruining them altogether; others are infected and the lint is damaged but not destroyed. The damage to bolls is considerably greater during years when there is much rain, especially during late summer and fall; it is greater in more humid regions, as in countries near the seacoast and in the Mississippi Delta; and on very rich land where plants become large. The damage is worse on varieties with large leaves. The heavy foliage shades the lower parts of the plants more completely, thus making conditions favorable for fungous growth.

The amount of damage varies greatly in different years, in different localities, and with the condition of the seed planted. Estimates made by different observers vary all the way from 6 to 60 per cent. Under certain conditions 25 to 50 per cent of the bolls may be rotted or less seriously damaged, but probably, on the average, the loss is not more than 1 per cent of the value of the crop.

*Symptoms of the Disease.*—Anthracnose attacks all parts of cotton plants except the roots of large plants. In case the seeds planted are infected, the fungus may attack the sprouts of the germinating seed and prevent further growth (Fig. 70). The failure of a large percentage of the cotton seeds that are planted to produce seedlings is doubtless to be attributed largely to this disease. During cool weather young seedlings only a few inches high are often attacked and injured or destroyed. The stem may be attacked either below or a short distance above the surface of the ground, the injury causing a "damping-off." It is rather difficult to distinguish this trouble from a damping-off caused by other organisms. Anthracnose, according to Atkinson,<sup>2</sup> causes tissue to redden somewhat and shrink in longitudinal lines; while the "sore-shin" attacks caused by *Rhizoctonia* produce well-defined ulcers, or diseased depressions of a brownish color, on the stems of seedlings just below the surface of the soil. These injuries are frequently outgrown unless the disease has penetrated the stems too deeply. On the cotyledons

of young seedlings, anthracnose produces irregular diseased areas around the edges.

Anthracnose sometimes attacks the stem of plants that are mature or nearly so. The infected areas are at first dull red, then black, and finally become pink if spores are produced. Stem infection usually occurs in places where plants have been injured or in leaf scars, the fungus living saprophytically in part. Stem infection sometimes causes the breaking down of branches, and the dropping of bolls. As a rule, injury to stems is not serious on Upland cottons. The stem lesions, however, may serve as a source of boll infection.

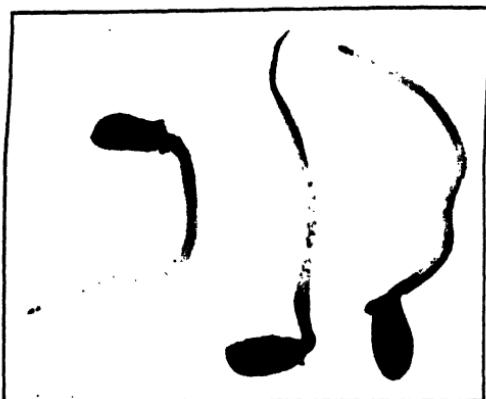


FIG. 70.—Seed from anthracnose-diseased cotton bolls sterilized externally and germinated in sterile Petri dishes. The fungus grew out from underneath the seed coats and attacked the sprouts in the black areas. (After Gilbert.)

The anthracnose fungus is, according to Atkinson,<sup>2</sup> frequently found on leaves of mature cotton plants, being more liable to develop on sickly or injured leaves. Converse<sup>14</sup> found that 90 per cent of the nectar glands of leaves of diseased plants contain the cotton anthracnose organism. This is probably an important source of infection for bolls.

Anthracnose disease is most characteristic on cotton bolls of mature or nearly mature size and it does most damage to the bolls. On the bolls the disease first appears as a small dull-red spot or spots. As the spots enlarge the tissue darkens; different spots may become confluent, covering one-fourth to one-half the boll. A little later, with the production of spores, the spot becomes grayish in the central or older part, and if the weather is moist, spores appear in such abundance that the center of the spot

becomes pink (Fig. 71). As the pink area enlarges, it continues to be surrounded by a rather well-defined dark border. Fungus threads enter the boll, arrest its growth if not full size, and cause a darkening and rotting of the parts within. Diseased bolls frequently become darkened and hardened throughout and never open; others crack, but the lint in the locks is weak and discolored, and does not become fluffy (Fig. 71). In many instances a part of the locks open normally, apparently, but the lint and seed in these are, in most cases, infected with the disease-producing organism.



FIG. 71.—Anthracnose of cotton. (After R. W. Harned.)

*The Causal Organism.*—*Glomerella gossypii* (South.) Edg. has a richly branched septate mycelium, usually hyaline but sometimes somewhat darkened. It grows in and between host cells, causing collapse, loss of chlorophyll, and browning. Mycelium grows throughout diseased bolls, entering seeds and lint fibers.

Conidia are formed in acervuli, subtended by stromata; acervuli erumpent; conidiophores, 12 to 28 by  $5\mu$ ; conidia irregularly oblong, hyaline, or flesh-colored in mass; setæ single or tufted, dark at base and colorless above, straight, rarely branched; setæ increase in number with the age of the acervulus, and conidia are occasionally found on them. Conidia in germination usually develop one septum, sometimes two septa, and produce dark

chlamydospores. Acervuli are common on bolls; less so and smaller on leaves and stems.

The perithecia, as found on cotton bolls in the field by Edgerton in Louisiana, were usually entirely imbedded, with the beaks only protruding, and were often numerous and crowded. Perithecia are described as being subglobose to pyriform. 80 to 120 by 100 to 160 $\mu$ , beak 0 to 60 $\mu$  long; asci numerous, clavate,

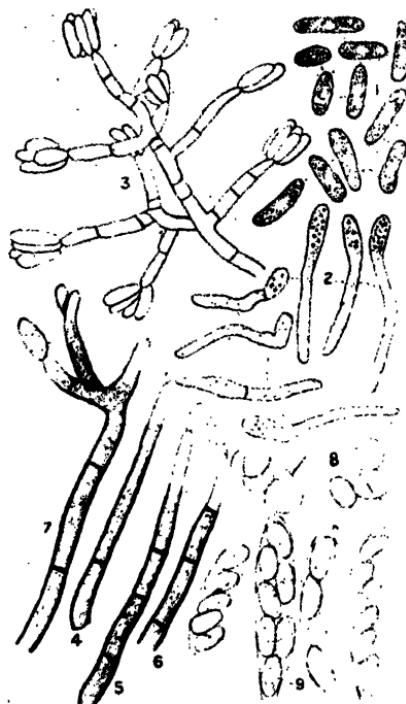


FIG. 72.—*Glomerella gossypii*: (1) spores, (2) spores germinating, (3) spore formation on mycelial threads, (4, 5 and 6), setae with spores in different stages of development, (7) a branched seta, (8) yeast-like cells formed in Elfring's nutrient solution, (9) asci and ascospores. (After Edgerton.)

55 to 70 by 10 to 14 $\mu$ , spores elliptic, hyaline, rarely curved, 12 to 20 by 5 to 8 $\mu$ ; paraphyses long and slender, very abundant (Fig. 72).

*How Cotton Plants Become Infected with Anthracnose.*—Barre<sup>12</sup> has shown that spores and filaments of the fungus may remain alive on old stalks and bolls in the field for a year, but not longer. When bolls were buried they lived only about 7 months. On

the outside of seed, spores retained their vitality for 9 months, but on the inside, spores or fungus hyphae lived as long as 3 years. Edgerton<sup>13</sup> found many spores on cotton seed, estimating the number as high as 800,000 per seed from apparently healthy cotton. Barre<sup>12</sup> found that many seeds which looked sound on the outside contained fungus filaments and spores capable of infection.

It is likely that diseased cotton seeds are the chief source of infection for the plants of a given crop. The organism in the seed attacks the germinating seeds, and if the weather is too cool for the young plants to grow rapidly, causes the death of many of them even before they get above ground. The disease spots on ones that do survive constitute a source of infection for other parts of the plant later. Infection is probably spread by water, especially the splashing of rain drops. Edgerton<sup>13</sup> has found that from 25 to 45 per cent infection on cotton bolls results from spraying a suspension of spores in water into open flowers. Barre<sup>12</sup> and Edgerton<sup>13</sup> have both shown that a high percentage of boll infection results from spraying suspension of spores on cotton bolls, the younger the boll the higher the percentage. Table XXXIV, from Edgerton, brings out this point.

TABLE XXXIV.—INFECTION EXPERIMENTS WITH BOLLS OF DIFFERENT AGES

Age of bolls, days	Number of checks	Per cent of checks diseased	Number of inoculations	Per cent of inoculations diseased
4	13	0	27	77.8
7	...	...	41	95.1
11	...	...	38	81.6
16	1	0	25	24.0
21	3	0	1	0.0
26	12	8.4	17	11.8
30	4	50.0	4	0.0
32	4	25.5	7	14.3

*Control Measures.*—Planting only seed from disease-free fields, the use of 2-year-old seed, the use of crop rotations, and fall plowing are control measures that have proved effective and of practical value. If it is not possible to gather seed from disease-free fields, picking cotton from disease-free plants is a help.

Since the fungus is not able to live on old plant débris for more than a year, a 2-year rotation in which some other crop is alternated with cotton serves to kill out the disease in the field. Running over the old stalks with a stalk cutter and turning them under thoroughly by fall plowing is helpful, because the organism lives a much shorter time when buried in the soil.

Other methods of control, such as sterilizing seed by the use of concentrated sulphuric acid and mercuric chloride, soaking seed in hot water for a few minutes, drying seed artificially to a moisture content of 2 per cent, using gases on seed, and spraying plants with Bordeaux mixture and other sprays, have been tried. Most of these measures were effective to a large extent, but they did not eradicate the disease entirely, and are not suitable for practical use.

*Varietal Resistance.*—Some varieties, such as Toole, Dixie, King, Dillon, Cleveland, Russell, Express, Rowden, Truitt, and Simpkins, are generally considered somewhat resistant to anthracnose; while Cook, Half and Half, Blue Ribbon, Brown, Columbia, Lone Star, Webber-49, and Triumph are regarded as susceptible. Inoculation experiments carried on by Edgerton<sup>16</sup> showed that there is practically no difference between different varieties in actual resistance after inoculation. Barre<sup>12</sup> also found that no variety possesses marked resistance. It is probable that the habit of some varieties makes them more susceptible to natural inoculation than other varieties.

**Rust or Black Rust.**—Rust, or black rust, also known under the names of yellow leaf blight, and potash hunger, is due to unsatisfactory cultural conditions, and is termed a physiological trouble. It is very common on the poorer soils throughout the Cotton Belt, and causes damage ranging from practically none to nearly total. Gilbert<sup>17</sup> estimates the average damage for the entire Cotton Belt to be from 4 to 5 per cent.

*Symptoms.*—Plants affected with the black rust fail to make normal growth, being small and of sickly green color. Toward the middle of the season the leaves take on a mottled appearance, yellow spots appearing over areas farthest removed from veins. These spots enlarge and become brownish, and later the whole leaf becomes somewhat blackened, curled up, and ragged. Most, if not all, of the leaves are shed prematurely; consequently, the bolls fail to develop properly. Many remain small and fail to open; others that do open have lint of very inferior

quality. The blackening of the leaves is due largely to attacks of *Alternaria* and other saprophytic fungi.

**Cause.**—Black rust of cotton is caused by improper soil conditions. No disease-producing organism initiates the trouble, but certain fungi attack the weakened or dead plants. Faulty soil conditions responsible are:

1. Lack of humus or vegetable matter in the soil.
2. Lack of potash.
3. Improper drainage.

Continuous cropping to corn and cotton without keeping up the supply of organic matter in the soil has put many fields in such a condition that cotton rusts badly. Rust also frequently develops on only the low lands of a field, or only after a period of continued heavy rains.

The growing and plowing under of green manures, such as rye, cowpeas, velvet beans, will usually check black rust. Ricks<sup>21</sup> and others have shown that a liberal application of barnyard manure or of kainit is effective in checking rust. Muriate of potash and other carriers of potash are also helpful.

**Angular Leaf Spot** (*Pseudomonas malvaccarum*, E. F. S.).—Angular leaf spot is the only bacterial disease of cotton of economic importance. Various names have been applied to this disease, as bacterial blight, bacterial boll rot, black arm, etc., according to the part of the plant attacked.

This disease is widely distributed in the cotton-producing states of the United States, and has been reported from Natal, the West Indies, and from several other cotton-growing districts. Leaves are attacked very generally, but the chief damage is to the bolls. A very small percentage of the bolls in a field of cotton are commonly infected, but an infection as high as 60 per cent has been reported. Rainy weather favors the spread of the disease.

**Symptoms.**—Angular leaf spot is most noticeable on the leaves, but it also attacks cotyledons, stalks, branches, bracts, and bolls. On the leaves the disease first causes dark-green angular spots on the under surface. These later show on the upper surface and become reddish brown. The brown spots rarely cross the veins. This is the cause of their angular shape (Fig. 73), but several spots may coalesce more or less along either side of large veins, making zigzag streaks. If the leaf is badly infected, it may curl up and drop off.

When the disease attacks the stem or branches, it causes a blackening of the parts affected, and it is then called black arm. This, according to Gilbert,<sup>17</sup> is worse on Egyptian and Sea



FIG. 73.—Angular leaf spot of cotton. (After Dr. E. F. Smith.)

Island cottons, which seem to be especially susceptible to the disease.

On the bolls the first signs of disease are small, dark-green, water-soaked, roundish spots. These spots gradually enlarge

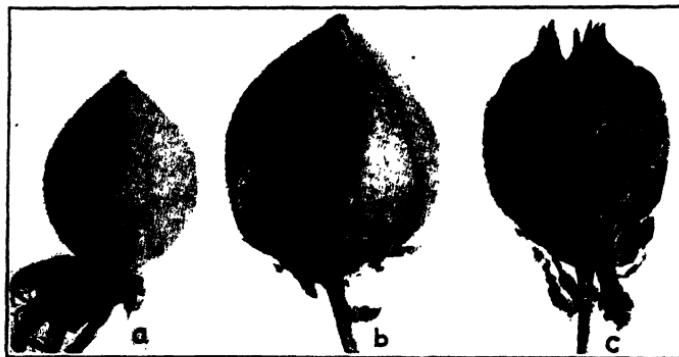


FIG. 74.—Bacterial boll-rot: *a*, early; *b*, intermediate; and *c*, late stages. (After Gilbert.)

and turn black in the center as the tissue is killed. Two or three locks or all the locks in the boll may be so injured that they fail to open (Fig. 74).

*Causal Organism.*—The angular-leaf-spot disease of cotton is caused by a bacterium (*Pseudomonas malvacearum*, E. F. S.), which is described by Faulwetter<sup>18</sup> as follows:

It morphologically resembles the other yellow, one-flagellate rods causing diseases of walnut, bean, hyacinth, citrus, etc. It is in the form of short rods, usually occurring in pairs or chains of three and sometimes more. The flagellae have been observed in young cultures. One, sometimes branched at the end, or occasionally two flagellae occur at one end, making possible very active motility. No endospores, granules or capsules have been demonstrated. Moderate growth takes place on all the sugar agar slant media.

Successful inoculations were made by E. F. Smith by spraying a suspension of young agar culture of the organism on cotton leaves and bolls. Numerous successful inoculations have also been made by Faulwetter, Rolfs, and others.

Initial infection in the spring probably results largely from bacteria that have wintered over on seeds and on lint attached to seeds. Primary infection is on the cotyledons of young seedlings; other parts of the plant are infected from these. According to Faulwetter,<sup>18</sup> infection is spread very largely by rain, and by rain and wind in case of storms.

*Control Measures.*—The use of disease-free seed is the only satisfactory control measure known. Seed may be sterilized with sulphuric acid and mercuric chloride, or with sulphuric acid alone. Gathering seed from disease-free plants is possible and may be of some value in practice.

**Texas Root Rot** (*Ozonium omnivorum*, Shear).—A form of cotton root rot known commonly as Texas root rot causes considerable damage to the cotton crop in Texas and smaller losses in Oklahoma, Arizona, New Mexico, and California. The disease has not been found east of Texas. In Texas alone the loss in 1906 was estimated at three million dollars.

This disease has been studied by Atkinson,<sup>2</sup> Shear,<sup>20</sup> Pammel,<sup>19</sup> and others.

*Symptoms.*—The general characteristics of the disease, as described by Pammel,<sup>19</sup> are as follows: The first indication is the sudden wilting of a single plant, or a number of them; this is apt to occur in May or June. During the last of June or the first of July a large number of wilted plants may be seen, later forming irregular dead patches. The plants wilt most frequently on

hot days following rain. Continuous dry weather tends to hold the disease in check.

If the roots of dead cotton stalks or of those wilting are examined, brown threads of fungus will be found closely surrounding the tap root and some of the lateral roots (Fig. 75). Small wart-like bodies, or sclerotia, are found in numerous places on the tap root and lateral roots. The roots shrink and decay.

The fungus mycelium in younger stages is white, and may be found on roots of plants that appear healthy.

*Causal Organism.*—The fungus causing Texas root rot is *Ozonium omnivorum*, Shear. Shear<sup>20</sup> describes it as follows:

It is a facultative parasite infesting the soil and attacking the roots of a great variety of plants, and causing serious damage to cultivated crops, such as cotton, alfalfa, cowpeas, beets, and fruit trees. Few crops except grasses and grains are free from it. No fructification is definitely known. Sterile mycelium is a dirty yellow, sometimes whitish when young or growing in cultures or in the vessels of vascular bundles of plants; hyphae

FIG. 75.—*Ozonium omnivorum* on roots of cotton. (After B. M. Duggar.)

forming strands and spreading from them, producing a rather dense arachnoid layer on the surface of the host and bearing one to four branches arising and growing at right angles from the same point near the ends; diameter 3 to 5 $\mu$ , tapering toward the ends.

*Control Measures.*—Since this is a soil-borne disease, great precaution must be used to prevent the transference of inoculated soil to disease-free areas. Soil is often transferred to carry legume inoculation, and this practice may serve to spread the disease.

Deep fall plowing and the use of immune crops, such as grains, two years in succession in a 3-year rotation is the only control measure advised, and even this is of doubtful value in many instances, as was shown by recent work of Scofield<sup>21</sup> at San Antonio, Tex.

**Diplodia Boll Rot** (*Diplodia gossypina*, Cooke).—Diplodia boll rot, according to Edgerton,<sup>13</sup> causes considerable damage to



the cotton crop in Louisiana, being worst on the alluvial soils and bluff lands. It is estimated that the average damage for the state as a whole is 2 per cent. No reports have been published giving losses elsewhere. Probably they are not serious.

Diseased bolls turn black, and after a short time become thickly covered with pyrenidia, which exude quantities of black spores, making the whole surface of the boll appear smutty. The contents of the boll become black and rotten.

Edgerton<sup>13</sup> found that inoculations were effective only when made in wounds on bolls; that spores in pyrenidia on old diseased bolls retained their vitality for 9 months; and that the disease was not seed-borne. Deep fall plowing which will bury all the old diseased boll is probably a satisfactory control measure.

The causal fungus, *Diplodia gossypina*, was described by Cooke, in 1879. His description is:

*Diplodia gossypina*, Cke. Gregaria, erumpens. Peritheci subconicis, atris, subitus applanatis, fibrosis. Sporis ellipticis, olivaceo-brunneis, 0.022 by 0.012 millimeters. On old capsules of gossypium, Bombay (India).

**Cotton Diseases of Lesser Importance.**—In addition to the more important cotton diseases that have been discussed, there are several others of minor importance that should be mentioned.

*Fusarium Boll Rot*.—A boll rot caused by a species of *Fusarium* (determined tentatively by Edgerton<sup>13</sup> as *Fusarium roseum*) does some damage to cotton bolls. This organism attacks only bolls that have been injured in some way, and lives, in the main, as a parasite, but at times, after getting a start in the boll, it grows into living tissues, and may also damage the lint in mature bolls.

This disease resembles anthraenose considerably in that spots on the bolls at certain stages are coated with pink spores; but the spot is not slimy, as in anthraenose spots, and the spores are a lighter color. Infection is carried over winter by the seed.

*Other Boll Rots*.—Boll rots are caused by *Rhinotrichum*, *Olpitrichum*, *Volutella*, *Selerotium*, *Botryosphaeria*, *Schizophyllum*, and several other fungi, but the damage done by these is not of importance.

*Areolate Mildew*.—This disease is also called frosty mildew, from the frosty appearance of the under side of the leaves. It is caused by *Septocylindrium areola* (Atk.), P. and G., a fungus

described by Atkinson, in Alabama, 1890. This disease is widespread, being especially common the latter part of the season on rank plants growing on fertile, moist soil. Although it causes some shedding of leaves, the economic importance is slight.

*Leaf Spot* (*Mycosphaerella gossypina* (Atk.), Earle; *Cercospora gossypina*, Atk.).—This disease is common on cotton, but it is of slight economic importance, since it attacks only weakened or old leaves. Small red dots first appear on the leaves. These enlarge centrifugally, the center becoming brown, and later white if spores are produced. In the last stages the leaves are ragged and full of holes.

*Rust*.—A true rust of cotton caused by *Kuehneola gossypii* (Lag.), Arth. has been reported from Florida, Cuba, Porto Rico, and British Guiana. Apparently, this is of but little economic importance.

*Cluster Cup Rust* (*Ecidium gossypii*, E. and E.).—This is another true rust, which has been found on cotton in Florida, Mexico, and Texas. The most serious outbreak on record occurred in Texas in 1917. Plants were partly defoliated, and the loss in infected fields was estimated at 20 per cent.

*Smut* (*Doassansia gossypii*, Lag.).—This disease has been found attacking cotton leaves in Ecuador and in the West Indies.

*Red-leaf Blight*.—Frequently when cotton is grown on poor soil the leaves tend to turn red late in the season, resembling the autumnal coloration of woody plants. This is a physiological trouble caused by lack of nutrient elements in the soil.

*Damping-off* (*Pythium de baryanum*, Hesse, and other fungi).—During seasons when the weather is too cool for young cotton plants to make proper growth, they are apt to be attacked by certain fungi that cause damping-off, or a soft rot of the stem at the surface of the ground or below.

*Sore Shin* (*Corticium vagum*; *Rhizoctonia*).—This disease attacks young seedling plants during cool, wet periods, and may damage the stand of plants seriously. The disease is characterized by the presence of dark rusty-brown cankers on the stem at or below the surface of the soil. These may penetrate so deeply that they cause the plant to bend over and die.

*Crown Gall* (*Pseudomonas tumefaciens* (S. and T.), Stev.) is mentioned by Stevens and Hall<sup>22</sup> as doing some injury to cotton.

*Club Leaf, or Cyrtosis*.—This is a serious cotton disease prevalent in the Yangtze Valley of China, according to Cook.<sup>23</sup> The

diseased plants show leaves reduced in size, discolored, and distorted; petioles and internodes are shortened; and the branching habits are changed. The exact cause of the disorder has not been determined.

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## CHAPTER XV

### COTTON INSECTS

The cotton plant has several different means of attracting insects. On the midrib on the under side of each leaf there is a nectary, a shallow cup-shaped structure that contains a droplet of sweet fluid; at the base of each bract on the outside of the square is another nectary; inside of the flower near the base of the petals are others. Many insects visit the plants to get the nectar. Others come to the cotton flower to gather or feed on the pollen. The tissues, or substance of seeds, leaves, stem, and roots of cotton plants, are rich or moderately rich in nutrient materials. These invite various insects to feed on the plants and, in some instances, to live within their tissues.

Of the many insects that visit cotton plants, a few are beneficial in that they foster pollination or prey on harmful insects. A comparatively small number of others are injurious to the plants. The greater number of the insect visitors may be classed as neutral, being of no help to the plants but doing no harm. Of the harmful insects the boll weevil, the pink boll worm, the cotton leaf caterpillar, and the boll worm are the most destructive. These will be discussed in some detail, and control measures mentioned. Several other insects of lesser importance will be considered briefly.

With the extension of cotton culture in the different cotton-producing countries of the world and with the transference of cotton seed for planting purposes has come the spread of harmful insects. Many countries have had no quarantine measures until recently, and did not realize the need of them until too late.

In the United States, the cotton leaf caterpillar and the boll worm were the only insects that did any considerable damage prior to 1892, and they appeared in serious outbreaks only occasionally. In 1892, the boll weevil crossed the Rio Grande River into Texas, and has since spread over practically all of the Cotton Belt east of New Mexico, and has damaged the cotton crops to the extent of hundreds of millions of dollars. Within

the last two decades the pink boll worm has been introduced into and has spread over much of the cotton-producing region of Egypt and Brazil. Recently, the pink boll worm was found in Texas, Louisiana, and New Mexico, and there is some danger that it may spread over the American Cotton Belt.

#### THE MEXICAN BOLL WEEVIL

The Mexican boll weevil, (*Anthonomus grandis*, Boh), which is by far the most destructive insect that has ever attacked the cotton plant in the United States, is a native of Central America or Mexico. All evidence indicates that it has fed on the wild tree cottons of those regions for many years past. Very little is known concerning the boll weevil in Mexico, except that it was generally distributed and did considerable damage many years previous to its entrance into Texas in 1892.

Boll weevils were found near Brownsville, Tex., in 1892, and since that time they have spread over nearly all of the American Cotton Belt. They did considerable damage in Texas in 1894, and entered Louisiana in 1903, Mississippi in 1907, and Alabama in 1909. The spread throughout the eastern Gulf states was rapid. The boll weevil is known as a cotton pest from Mexico southward to Costa Rica and in Cuba. Other cotton-growing districts are free from weevil infestation. Figure 76 shows in detail the spread of the boll weevil over the Cotton Belt.

*Anthonomus grandis thurberiae*, Pierce, a variety of boll weevil distinct from the common weevil, but belonging to the same species, was found feeding on the wild cotton, *Thurberia thesperoides*, in the mountains of southeastern Arizona, in 1913. In 1920, it was seen on cultivated plants north of Tucson.

**Description and Life History of the Boll Weevil.**—The adult boll weevil is a small grayish or brownish weevil, about  $\frac{1}{4}$  inch in length varying from  $\frac{1}{8}$  to  $\frac{1}{3}$  inch with a breadth one-third of the length. The size varies considerably, being determined by the amount of food supplied the developing larva. Weevils that develop in bolls, where food is abundant, are considerably larger than ones that grow in squares. The color is largely dependent on the age of the weevil; newly hatched ones are yellowish brown, while older ones become grayish and darker. Figure 77 shows the shape and general appearance of the adult weevil. The ridged or lined appearance of the wing covers and the two

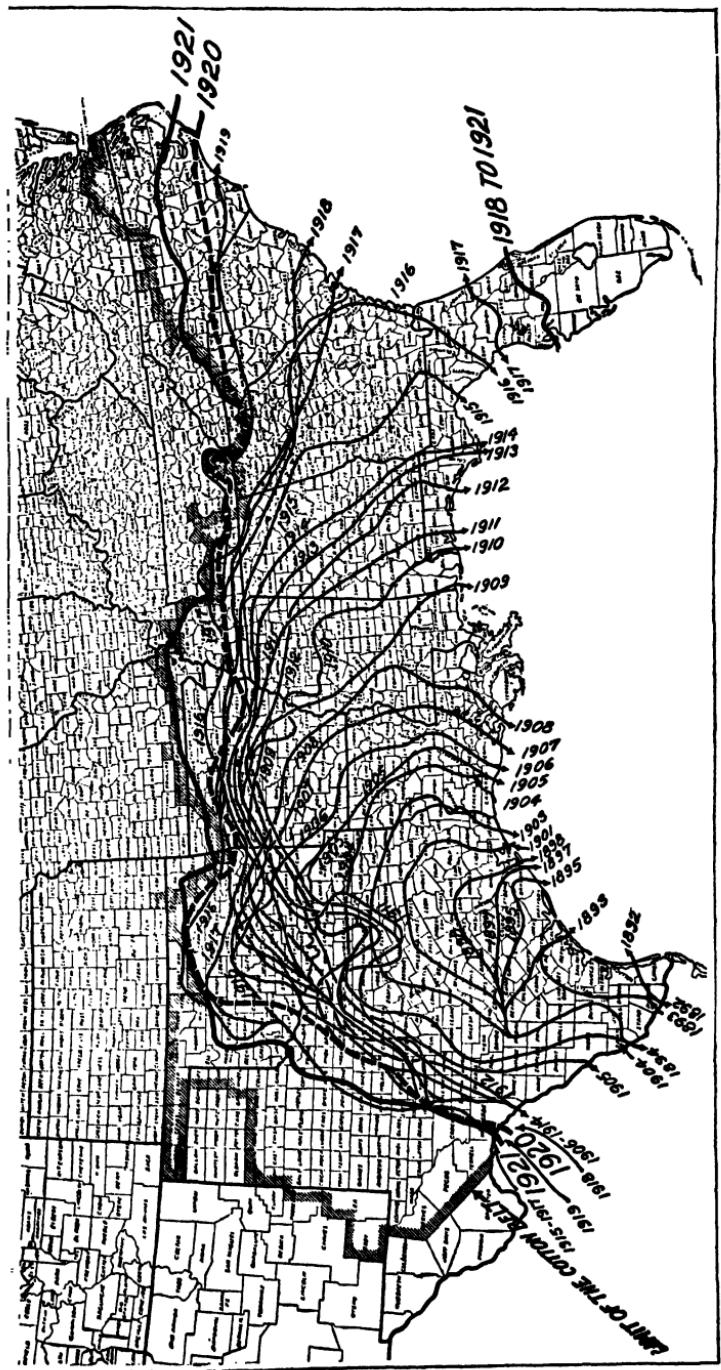


FIG. 76.—Map showing dispersion of the Mexican cotton boll weevil in the United States from 1892 to 1921.

(Note: The outer limit of the cotton belt advances or recedes slightly from year to year and in the map is not absolutely accurate for 1921, as shown by the fact that in a few places the boll-weevil line is a little in advance of the indicated limit of cotton culture. (Bureau Entomology, U. S. Department of Agriculture.)

projections at the outer end of the first joint of the front legs are distinguishing marks helpful in determining whether or not a specimen is a boll weevil. Anyone who has once seen boll weevils will have but little trouble identifying them. In a cotton field the presence of weevils is indicated by the flaring of the bracts

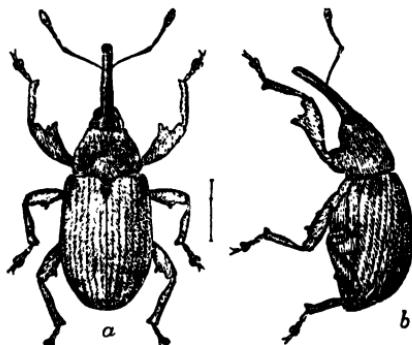


FIG. 77.



FIG. 78.

FIG. 77.—Much enlarged picture of adult boll weevil, showing hairy covering, snout, antennæ, and the two small teeth on projections on the front leg. Line indicates true size. (After W. D. Hunter, U. S. Department Agriculture.)

FIG. 78.—Square showing position of boll weevil egg puncture near base of flower bud. (After Smith.)

of cotton squares and by an excessive amount of square shedding. If the squares when cut open are found to contain a white, curved grub that has eaten out the inside of the flower bud, there is not much doubt that boll weevils are present.



FIG. 79.—Cotton boll weevil; larva at left, pupa at right; about three times natural size.

The boll weevil passes through the winter, or hibernates, in the adult or winged stage. Egg laying does not begin until cotton squares have formed. Eggs are deposited in small pits or openings which the female makes with her snout. They are usually placed near the base of the flower bud and inside the corolla (Fig. 78). A hibernated female, as shown by Smith,<sup>1</sup> lays, on the average, seventy-six eggs, but some under observation laid as many as 218 eggs. As a rule, but one egg is deposited in a square.

The egg under normal conditions hatches in about 3 days, and the larva, or young grub, begins to feed on the plant substance

about it. It reaches maturity in about 7 to 12 days. Its development is dependent on weather conditions; cool weather retards growth, while hot, dry weather may kill it. The mature larva is white with brownish markings, curved, and about  $\frac{1}{2}$  inch in length (Fig. 79). The mature larva changes into a pupa, a form corresponding to the chrysalis of the butterfly or the cocoon of the moth (Fig. 79). The pupa is inactive, eats nothing, and remains within the square or boll. After 3 to 5 days an adult weevil hatches from the pupa. The young adult begins to produce a new generation in from 5 to 7 days after emergence. The condition of the weather has an important bearing on the length of time required for a boll weevil to pass through its life cycle. The time required varies from 2 to 4 weeks or longer, being longer during cool weather or towards the end of the season. Warm weather favors rapid development, but hot, dry weather increases mortality greatly.

The length of time that the mature weevils live varies with the season of the year. In the summer, according to Hunter,<sup>2</sup> most weevils do not live longer than 50 days. During the cooler part of the year, many live as long as 6 months, and one is known to have lived from December to the following October—11 months.

**Food of the Boll Weevil.**—The favorite food of the boll weevil is pollen in the unopened flower bud of the cotton plant. This it obtains by making a number of punctures through the corolla of the unopened flower. The upper part of the bud may show a dozen or more punctures with loose pollen scattered around them. Weevils that appear in fields before squares have formed attack the young leaf buds to some extent, and, in the latter part of the season, after unpunctured squares have become scarce, they attack young bolls. Even bolls of full size, but with tender walls, may be punctured.

Apparently, the young pollen grains of the medium-sized flower bud are the favored food of the weevil larvæ. The mother weevil deposits the egg inside the bud among the anthers of the flower, so that the first food of the young grub may be pollen. Later in the season, after squares have become scarce, a good many young bolls are punctured and eggs are deposited in them. The developing larva either ruins the boll completely or damages it badly.

The cotton plant constitutes almost the sole food of the boll weevil. In 1913, a boll weevil was observed at Victoria, Tex., feeding on *Hibiscus syriacus* (Howe,<sup>3</sup>) a plant botanically related to cotton. Since that time cage experiments and field observations have been conducted which go to show that the weevil can live for a time at least on plants closely related to cotton. The most important of these seem to be the various wild species of Hibiscus and okra and the wild cotton of Arizona. Occasionally, eggs have been deposited on Hibiscus, but never has a case of breeding on okra been recorded. When confined in bottles, adult weevils feed rather freely on the kernels of cotton seed, and have been observed, under the stress of starvation, to eat various other substances, such as apples, bananas, etc.

**Nature and Amount of Boll-weevil Damage.**—Both the adult weevil and the larva damage cotton plants. The adult feeds on young leaf buds, and punctures both squares and young bolls for feeding and egg laying. The larvae feed on the inside of squares and bolls. The squares are shed or fail to develop flowers. Young bolls are commonly shed, while older ones have one or more locks ruined. Some locks that open have the lint so stained or damaged that the grade of the whole lot of lint cotton is lowered.

The damage done by boll weevils varies largely in different localities, and even in different fields of the same locality. The cause of much of this difference is difficult to explain. For some reason, the weevils fail to appear in certain fields in sufficient numbers to do much damage until many bolls have been put on and a good crop made. The amount of damage done in different years varies much also, owing to differences in the weather. Rainy or cloudy weather during the period the plants are blooming most, or during the latter part of June, in July, and the first half of August, is conducive to heavy weevil damage. Hot, dry weather during the same period serves to hold the weevils in check on account of the heavy mortality of the larvae. Some squares become so dry while still clinging to the plant that the larva or pupa within perishes, and others that fall on the hot ground become so heated that these immature stages are killed. A warm or open winter is favorable to weevils, because a high percentage, comparatively, survives the winter and are ready to multiply in the spring. Low winter temperatures, however, are not as effective in control of the weevil as once thought, and

certainly not so effective as dry weather during the summer. The writer has seen a heavy initial infestation in central Mississippi following a winter during which the temperature dropped to zero at two different times.

The damage, as was pointed out above, varies greatly in different localities, ranging from less than 5 per cent to practically total loss. The Bureau of Crop Estimates of the U. S. Department of Agriculture, in the fall of 1920, estimated that the average annual loss for the American Cotton Belt for the 4 years just preceding was \$300,000,000. This was direct loss due to the non-production of seed and lint. The usual loss when cotton values are lower is not quite so great, but it is enormous. In addition to the direct loss, there are others of immense importance occasioned by the damage to the cotton crop, as fall in price of land, depreciation in value of gins or oil mills that have to close or do a limited business, depreciation in railroad values, etc.

**Movement of Weevils.**—The boll weevil after landing in a cotton field shows but little disposition to leave if squares are plentiful. It flies for short distances, but is not apt to fly to another field until the seasonal migration period in August, unless food becomes scarce. When the migration period comes on, it instinctively takes to wing and by a series of short flights may travel a hundred miles or more. The movement is usually in the direction of the prevailing wind, but it may be in any direction. In the fall, beginning about the time of the first frost, there is also a movement to hibernating quarters. This flight is usually short and is terminated when a hibernating place is found. In the spring there is a movement from the hibernating quarters back to the cotton fields, the flight continuing until the cotton plants are found (see Fig. 76 for the spread of weevils over the Cotton Belt).

**Hibernation.**—By "hibernation" is meant the act of passing through the winter period in a dormant, or quiescent, state. With the coming of cool weather in the fall of the year, boll weevils begin to seek shelter. Many enter cracks in the ground or hide under grass, weeds, or other trash in the cotton fields. Others fly to fence rows, grassy ditch banks, or the woods, for shelter. The bunches of Spanish moss hanging from limbs of trees so abundantly in sections of the cotton states afford splendid winter quarters. Most weevils that attempt to pass

the winter in the cotton fields fail to survive. Apparently, woods, negro cabins, or hay stacks afford the safest places, for infestation in cotton fields early in the season is usually heaviest near such places.

During the winter period the weevils take no food and are practically inactive. When warm days come they may move about feebly. In the parts of the belt farthest south the hibernation is shortest, and there is more moving about during the period. In northern Florida, in 1918, Smith<sup>1</sup> found that weevils did not enter hibernation until about Dec. 7, and began coming out on Feb. 10. Farther north the period lasts from the middle of November to the first of March. In Texas more than 50 per cent of the weevils emerge in March; in Louisiana, about 25 per cent. Emergence begins in March or earlier in nearly all states, and continues until about the middle of July. It comes in waves, which are influenced by temperature and rainfall.

In a series of hibernation experiments carried out in Texas and Louisiana from 1906 to 1911 the average survival was 6 per cent. This probably represented about the percentage of survival in nature for the localities where the experiments were conducted. In colder regions the mortality is greater.

**Control Measures for Boll Weevils.**—Boll weevils reproduce with such rapidity that the offspring from a single pair, if all survived, would total several millions in one season. Fortunately, several natural agencies tend to hold them in check. The most important of these are hot, dry, summer weather and insect parasites that prey on the weevil larvæ. There are also fairly satisfactory artificial means of control.

**Natural Means of Control.**—As was pointed out above, hot, dry weather causes heavy mortality of the immature forms of boll weevils. When infested squares fall on dry ground and land where the sun's rays will reach, they become so heated that the immature weevils within are killed. Others perish in squares that dry up while still clinging to the plants. The immature weevils are not able to escape from the squares.

A very large percentage of hibernating boll weevils perish. Cold weather during the winter is responsible for a part of the mortality.

There are also a number of small insects that prey on the boll weevil. These serve as another natural method of control, and one of much importance. Forty-five species of weevil

enemies have been identified. A large number of these are parasites which deposit eggs on the larvæ or pupæ within the cotton square. The young of the parasite feed on the substance within the body of the immature weevil and eventually destroy it. Boll-weevil parasites are much more plentiful in certain localities than in others. This probably is the reason why the weevil damage is much less in some regions than in others with apparently the same climatic conditions. Hunter<sup>2</sup> states that in one instance, in 1907, in a field near Robson, La., the mortality due to parasites was 77 per cent, and in a field at Victoria, Tex., 61 per cent. Recent studies in various parts of Mississippi, made by Allen of the Mississippi State Plant Board, showed an infestation ranging from 40 per cent downward. These parasites have doubtless been in the country for a long time. Prior to the coming of the boll weevil they fed on other closely related weevils, which were not very abundant. The presence of large numbers of well-fed boll weevil larvæ invited them to make a change. There is a possibility that in the course of time parasites may become so plentiful that they will help greatly as a control measure.

In addition to the parasites just mentioned, there are other insects that feed on the boll weevil, the most important of which are ants. Twelve species of ants are known to attack the weevil. They are the small brownish or yellowish ants that run about over the ground and plants in cotton fields. They gnaw into the infested squares, both when hanging on the plants and on the ground, and soon destroy the helpless grub inside. Hunter<sup>2</sup> reports that in some cases half of the immature stages in fields have been destroyed by ants.

Birds render some service by catching adult weevils.

Plant cells, in the effort to heal the wound made by the weevil in puncturing the squares or bolls to deposit an egg, may exert such pressure on the egg or young larva that it is crushed. This is spoken of as proliferation.

**Artificial Control.**—The control of boll weevils by artificial measures is a very difficult matter. The young develop inside the flower bud, where they cannot be reached with a poison, and the adults are so protected by the foliage and flower parts that they cannot be collected to any advantage or poisoned with a contact poison. The Bureau of Entomology of the U. S. Department of Agriculture and different experiment stations in the

Cotton Belt have labored long and hard to find some control measures that will be of practical use in the cotton fields. Hunter and Coad<sup>4</sup> give a good digest of the results obtained from various boll-weevil control experiments, and make recommendations based on the best information available at present. They say:

There are the direct and indirect methods [of control], both of which are of vital importance. The importance of indirect methods is often more difficult for the farmer to appreciate than that of the direct; but, in reality, successful weevil control cannot be accomplished unless full advantage is taken of every possible method, and the campaign must be based upon a combination of the different methods rather than concentrating all efforts on direct control.

The farmer is aided in his fight against the weevil by a number of important natural factors which tend to reduce the possible weevil damage. Some of the more important of these which must be taken into consideration in planning a fight on the weevil are as follows:

1. The weevil is practically dependent on cotton for reproduction.
2. The mortality of the weevil during the winter is very high.
3. Hot, dry weather during the summer exercises a tremendous control upon the weevil stages, while moist, cloudy weather removes the control and greatly accelerates multiplication.
4. The weevil is attacked by many different species of insect enemies.
5. The emergence from hibernation quarters during the spring is slow and prolonged until well into the summer.
6. Early in the season, on account of comparatively lower temperature, the development of the weevil is much slower than during the midsummer months.
7. The cotton plant produces many more squares than it can carry to maturity as bolls. This surplus is shed by the plant throughout the season, under normal conditions about 60 per cent of the fruit being shed.
8. Up to a certain point, weevil puncturing of fruit does not reduce the cotton crop, because large numbers of forms would be shed normally.
9. The weevil has a decided tendency to seek moisture wherever it may be found on the surface of the plant.

**Direct Control by Poisoning with Calcium Arsenate.**—In the years which have elapsed since the advent of the boll weevil into the United States, every conceivable means of direct control of the weevil has been tried repeatedly. Owing to the peculiarities of the weevil attack which have been mentioned, most of these attempts have been unsuccessful. Some methods were found which would control the weevil, but these were either impracticable or too expensive for use on a commercial scale. During comparatively recent years, however, a method of poisoning has been developed which has proved very successful. This consists of treatment of the plants with powdered calcium arsenate by a specialized method.

It has long been known that poisoning the boll weevil is possible to a certain extent, but on account of the peculiar habits of the insect it was difficult to develop methods for the application of the poison.

The first question which occurs to the cotton farmer contemplating poisoning is whether it will pay to do so. From the following, any cotton grower should be able to determine the question for himself:

It will pay to poison—

If the weevils are really injuring your crop seriously; and if your land is sufficiently fertile to yield at least one-third bale per acre with weevil injury eliminated; and if your farming organization is such that you feel assured that the poison application will be made at the right time and in the right manner; and

If you are willing to spend the full amount necessary to provide an adequate amount of dusting machinery and poison.

You should not poison if the cost of the calcium arsenate, the cost of the labor to apply it, and the depreciation on the dusting machines will total more per acre than the current value of 100 pounds of seed cotton.

Hand guns should be figured as depreciating 50 per cent in a season and the larger machines about 25 per cent.

The next important question is that of the dusting machinery which should be used. Extensive experience has shown that it is impossible to get satisfactory results by using makeshift devices to apply the poison, and the only safe procedure is to provide an ample supply of the specialized dusting machinery which is now on the market for the treatment of cotton for the control of the boll weevil. Machines of various types, prices, and capacities are now being manufactured which meet the requirements and circumstances of almost all classes of growers. The following is a brief description of the several types and their uses:

The hand gun is the smallest type of cotton-dusting machine, and, as the name implies, must be carried and operated by the laborer. These machines are generally quite unsatisfactory, owing to their necessarily frail construction and laboriousness of operation. The selling price ranges from \$12 to \$25 each. *They should be used only when no other machine is suitable.* Not more than 8 acres should be allotted to one hand gun, and it has generally been found inadvisable to attempt the treatment of more than 25 acres of cotton in one organization with hand guns.

The one-mule machine is the smallest of the traction type of dusters. It is a one-wheel, one-mule machine, which the operator handles as he would handle a walking cultivator or any other walking implement. The machine has two nozzles and will treat either two or three rows of cotton at a trip, thus covering from 15 to 20 acres in a night of operation. It should be allotted not more than 60 acres of cotton throughout a season. This machine is now selling at from \$100 to \$125.

The cart machine is a two-wheel two-mule machine, which straddles a row of cotton. It has three nozzles and will cover from 25 to 30 acres of cotton in a night of operation. It should be allotted not more than 100 acres of cotton for treatment through the season, and is the type most suitable for large farms. This machine is now selling from \$250 to \$400.

In the early stages of the dusting work an engine-power machine was tried and a few of these are still in use, but it has been found that they are generally too complicated for satisfactory operation except by expert labor. Still other types of machines to suit different conditions are in the process of

development, but the present supply will meet almost any conditions fairly well.

The following condensed rules have been prepared for the guidance of those planning to poison:

Use only pure calcium arsenate in the form of a dry powder.

Apply this only in the dust form.

Purchase this to conform to the following specifications:

Not less than 40 per cent total arsenic pentoxide.

Not more than 0.75 per cent water-soluble arsenic pentoxide.

Density not less than 80 or more than 100 cubic inches per pound.

Use only dusting machinery especially constructed for cotton dusting.

Poison only when the air is calm and the plants are moist. Practically, this means making only night applications.

Use about 5 to 7 pounds of calcium arsenate per acre for each application.

Start poisoning when the weevils have punctured from 10 to 15 per cent of the squares.

Keep your cotton thoroughly dusted until the weevils are under control.

This usually means about three applications at the rate of one every 4 days.

Then stop poisoning until the weevils again become abundant.

If the weevils become abundant early enough to injure your young bolls, make one or two more applications late in the season.

If you have a heavy rain within 24 hours after dusting, repeat this application immediately.

Do not expect to eradicate the weevils. Poisoning merely controls them sufficiently to permit a full crop of cotton, and you can always find weevils in the successfully poisoned fields.

Keep your cotton acreage low and do everything possible to increase your yield per acre, as it costs just as much to poison one-quarter-bale-per-acre cotton as a bale-per-acre cotton.

Always leave an occasional portion of a cut unpoisoned for comparison with the adjoining poisoned tract. This will show how much you have increased your yield by poisoning.

*Indirect Means of Control.*—In addition to the use of poison, there are numerous other practices which tend to reduce the weevil injury, some of which are of general value, while others can be used only locally. The following pages list a few of the more important of these measures. Even when poisoning is practiced, the most thorough attention should be given to the indirect means of control, since they reduce the amount of poisoning which might be necessary and increase the profit which may be secured.

*Fall Destruction of Infested Plants.*—One of the most important steps towards reducing the weevil infestation, when it can be practiced, is the destruction of the cotton plants in the early fall, before the weevils have hibernated. To be of the greatest value, however, the plants must be completely destroyed by fire or plowed under deeply before the first killing frost, and this limits the use of this control measure to the districts where conditions are such that the entire cotton crop can be picked in time to permit such an early plant destruction.

For many years preceding the development of the calcium arsenate method of control, removal of the cotton plants from the field as early as practicable in the fall was advocated by this department as the most important step in controlling the weevil. The purpose of this operation is to destroy as many as possible of the immature forms of the weevil still remaining in bolls and squares. These immature forms, if undisturbed, transform into weevils which live over winter and lay eggs the following spring. Fall destruction of plants likewise eliminates hibernating places of the weevil in the field.

*Grazing.*—In some districts where it is impossible to practice fall destruction of the plants, somewhat the same results can be accomplished by grazing the field with cattle, sheep, or goats. This is only a local measure, however, since the supply of livestock in regions where the bulk of the cotton crop is produced is not sufficient for the purpose. Even when poisoning is practiced, fall grazing is still advisable, and no danger need be apprehended of poisoning the stock, since there is rarely sufficient poison on the plants to injure stock, even immediately after application, and, furthermore, a considerable period of time generally elapses between the last poison application of the season and the earliest grazing.

*Sprout and Volunteer Cotton.*—Considerable local difficulty in the control of the boll weevil is experienced in southern Texas and occasionally in Louisiana, owing to the presence of stumpage or sprout cotton. Sprout plants are sometimes encouraged, because they produce a small but very early crop. This may have been defensible before the advent of the boll weevil, but at present the practice is undoubtedly the worst that could possibly be followed. The weevils seek out these plants in the early spring and produce progeny much earlier than they otherwise could, and these progeny infest the planted cotton at an abnormally early date. Volunteer cotton causes the same results over a considerable portion of the Cotton Belt. The cotton seed scattered about seed houses and gins and along roadsides frequently produces plants which furnish early-season breeding places for the weevil. Needless to say, all such plants should be destroyed.

*Destruction of Weevils in Hibernation.*—It is often possible for the farmer to reduce considerably his spring weevil infestation by proper winter clean-up measures around his fields. The weevils will hibernate successfully in any trash or rubbish, and it is a very good practice to burn over or clean up any such situations around the cotton field during the winter, especially the fence rows and ditch banks.

In addition, much can be accomplished by the elimination of the hibernation quarters. Especially along the more northerly portions of the weevil zone, the most successful hibernation is largely confined to the timbered areas, and as a result serious weevil injury is experienced only in the fields adjoining such timber. Under such conditions it is of the utmost importance to plan all clearing operations so that the open areas for cultivation are consolidated into as large tracts as possible, and thus increase the amount of land which is sufficiently distant from timber to suffer a minimum amount of weevil injury.

*Locating Fields to Avoid Weevil Damage.*—Nearly every farmer who has been raising cotton for a few years in the presence of the boll weevil knows

that there are certain fields on his place where the weevils always appear first and in greatest numbers. With this information as a basis, it is sometimes possible to reduce the damage by refraining from planting cotton in such fields and planting the more distant fields. This practice, however, is advisable only when no attempt is made to control the weevil by poisoning. The fields adjoining timber where the weevil infestation is heaviest are usually the new lands of the place, and are thus the most fertile and capable of producing the best cotton crop if the weevil injury is eliminated. Furthermore, when such fields adjoin hibernation quarters, the weevils concentrate on them instead of scattering over larger areas, and they serve to a certain extent as trap crops, making it possible to poison the weevils on these fields and thus prevent their spread over the remainder of the crop.

*Procuring an Early Crop of Cotton.*—The foregoing facts relative to the life history, hibernation, emergence, and multiplication of the weevil show very plainly the importance of producing the cotton crop just as early in the season as possible. In reality, the production of cotton in the presence of weevils is nothing more or less than a race between the setting of bolls on the plant and the multiplication of weevils, and everything possible should be done to aid the cotton plants in winning this race. The following are some of the more important steps which may be taken.

*Early Removal of Plants and Preparation of Land.*—The first step in producing an early crop is the removal of the plants, so that the land may be plowed during the fall and winter and the seed bed thoroughly prepared. Just how much can be done is, of course, a problem for the individual farmer to determine and depends largely upon labor and weather conditions, but the importance of a well-prepared, solid seed bed can hardly be overestimated. Furthermore, unfavorable weather conditions shortly before planting often prevent plowing at that time, and early preparation does away with the risk.

*Use of Early Varieties of Cotton.*—One of the most important steps which have been taken to reduce the weevil damage has been the development and introduction of varieties of cotton which mature their crops earlier in the season than those varieties which were planted before the weevil invasion. The variety to be planted in order to obtain a profitable crop under weevil conditions will depend upon a number of factors as well as on the severity of the infestation. The soil, climate, and other factors must be considered. In many localities it is extremely important to select varieties which are resistant to diseases. The first effect of the boll-weevil invasion was to force the abandonment of the longer-staple and large-boll varieties of cotton and the adoption of small-boll, early varieties of very short staple, such as King and its derivative, Simpkins. During recent years, however, numerous other varieties have been developed to the point where they are sufficiently early to mature a crop in the presence of the weevil, and these are being rapidly adopted. The Triumph variety is one of the best known for the western portion of the infested territory. Among the others which have been cultivated with success in various localities are Cleveland Big Boll, Cook's Improved, Rowden, Toole, Brown, Lone Star, Trice, and Columbia.

The long-staple cotton situation is particularly interesting. The Upland long staples, which were cultivated when the weevil arrived, were slow-

maturing, non-prolific varieties with a very thin boll wall, and were thus subject to a maximum amount of weevil damage. The weevil soon eliminated practically every one of these varieties, and for some time it appeared that the production of long-staple cotton would be practically prohibited. The situation, however, has been met by the development of several long-staple varieties which are prolific and reasonably early. Among the best known of these are such varieties as Express and Webber.

**Early Planting.**—Another step to be taken in obtaining an early crop, and fully as important as those that have been mentioned, is early planting. No set rule can be laid down as to the proper date of planting. There is much variation in the seasons. Sometimes it is impossible to place the fields in readiness as early as is desirable, and much of the effect of early planting is lost unless the seed bed is in good condition. Rather than plant abnormally early, it would better to improve the seed bed. It is not recommended that planting be done at dangerously early dates. Nevertheless, with proper preliminary attention to the fields, it is possible for farmers in most localities to plant from 10 to 20 days earlier than they were accustomed to plant before the arrival of the weevil. It is much better to run the risk of replanting, provided the seed bed is in good condition, than to defer planting on account of the danger of cold weather. Of course, it is possible to plant entirely too early, so that the plants become stunted during the early days of their growth, and planting should not be done so early as to have this effect upon the plants.

**Fertilizers.**—An important step in procuring an early crop is the use of commercial fertilizers. In many large areas in the Cotton Belt the land is not impoverished to the extent that it actually needs fertilizers under normal conditions, but it has been demonstrated many times by the different experiment stations in the South that the maturity of cotton frequently can be hastened materially by the use of fertilizers. On impoverished soils, moreover, fertilizers containing a high percentage of nitrogen give increased yields under boll-weevil conditions.

**Florida Method of Boll-weevil Control.**—A method of control somewhat different from the one outlined in the preceding pages has been devised by Professor Smith of the State Plant Board of Florida. A short time after all boll weevils have come out of hibernation all the squares on the cotton plants are removed by hand and destroyed. The plants are then dusted with calcium arsenate, especially the buds at tip of stem and branches. The immature weevils are destroyed by the square removal and adult forms are poisoned. This method of control seems to have given good results in Florida, but it is doubtful if it will be satisfactory farther north where weevil emergence is much later.

**Objections to the Use of Calcium Arsenate.**—Serious drawbacks to the use of calcium arsenate in boll-weevil control are:

1. It costs so much to buy the poison and machines and to hire the labor necessary to apply the poison that it is not recom-

mended for land that will not make one-third of a bale of cotton to the acre. Much of the land of the Cotton Belt does not yield that amount.

2. The work must be done at night largely, which makes it disagreeable and costly.

3. During rainy seasons, when the control is most needed, it is a difficult matter to keep the poison on the plants, and the ground is so soft that the machines will not run well.

4. Lice usually multiply on plants that have been poisoned, causing a partial defoliation and a lowering of the grade of the lint cotton produced.

5. The gain in yield is very frequently not sufficient to offset the expense of the poisoning.

**Importance of Cultural Methods.**—Under the boll-weevil régime it is very important to have a full stand of cotton plants and to space them closely—close enough that all the space between plants in the row will be covered early in the season. With wide spacing, in course of time the plants may become large enough to cover all the space in the row and yield in proportion to the space occupied; but if weevils are plentiful, they prevent the formation of fruit the latter part of the season and, consequently, there will not be as much fruit put on as there would be in a row containing more but smaller plants.

It is also necessary to have land well drained, so that the crop can be planted early and cultivated properly. Cultivation should be frequent and thorough enough to keep down all grass and weeds, and to allow the plants to grow freely. One cultivation a week is a good rule. Cultivation should be continued late in order to keep the plants growing and forming squares until there is a good crop of large bolls. As long as there are plenty of squares for the weevil to attack, they will not bother the bolls seriously. It pays to continue plowing as long as there are numerous bolls liable to weevil damage. In the central part of the Cotton Belt cotton should not be "laid by" before the first of August.

**Ineffective Methods of Control.**—On account of the severity of boll-weevil damage and the difficulty in controlling it, a great many different methods of control have been proposed, many of which are of no value or are impracticable. The Entomological Laboratory at Tallulah, La., has tried out a great variety of control measures that have been proposed. The following dis-

cussion from Hunter and Coad<sup>4</sup> is based largely on results secured at that laboratory.

*Late Planting.*—Late planting is foremost among the futile means of control. At various times it has been suggested that late planting, especially if following early fall destruction, would so lengthen the hibernating period that no weevils would survive. Very numerous experiments in the field and in cages have proved that the weevils in considerable numbers are able to survive from any reasonable time of early destruction in the fall to beyond the date in the spring when any return whatever could be expected from planting cotton, even if the weevils were entirely eliminated. In a field experiment in Kerr County, Texas, the plants were removed very thoroughly early in November. Neither stumpage nor volunteer plants were allowed to grow during the winter. No other cotton was planted within 9 miles. On the experimental field, planting was deferred until June 10. In spite of this fact, weevils appeared as soon as the plants were up, and multiplied so rapidly that the production was not sufficient to warrant picking. Similar experiments under different conditions by the State Crop Pest Commission of Louisiana agree in every way with those of the Bureau of Entomology in Texas.

*Weevil and Square Collection.*—The possibility of weevil control by hand picking of the adult in the early spring and of the infested squares later in the season has been thoroughly tested on numerous occasions. Undoubtedly, this method is efficient when practiced with sufficient thoroughness, but numerous attempts to carry it out on a practical scale have shown that the labor difficulties are almost always prohibitive. This work is of value only comparatively early in the season and thus falls at the same period when there is a very heavy demand for the labor for other purposes, and it is generally impossible to collect the weevils or infested squares without neglecting other more important work. Consequently, this procedure can be recommended only under rare conditions, when the infestation is not excessively heavy and an abundance of cheap labor is available.

Many attempts have been made to collect the weevils by means of mechanical devices. Hundreds of such devices have been tested and all are to be condemned. They do not collect an appreciable number of weevils unless they are so violent in the agitation of the cotton plant that they are actually injurious to it.

*Trap Rows.*—The idea of attracting weevils to a few early plants or trap rows has frequently been advanced. Practical experience, however, has shown that the only possibility of success in such a procedure lies in the use of entire fields adjoining hibernation quarters, the fields to be poisoned later. The use of a few rows as a trap crop has been found to be absolutely valueless.

*Attraction to Lights.*—Many insects more or less resembling the boll weevil are attracted to lights. Many attempts have been made to destroy the cotton pest by taking advantage of this supposed habit. The boll weevil, however, is not attracted to lights. Numerous tests have been made in which many thousands of other insects were collected around strong lights in cotton fields, but not a single boll weevil was found, in spite of the fact that there were multitudes of these pests in the fields surrounding the lights.

*Chemical Treatment of Seed.*—Any money expended by the farmers in attempting to destroy the boll weevil by soaking the planting seed in chemicals in the hope of making the plants that are to grow from them distasteful or poisonous to the insects would be entirely wasted. The same remark applies to the various proposed treatments of the plants or soils with chemicals which are supposed to be taken up by the plants to the detriment of the weevils feeding upon them.

*Topping of Plants.*—The topping of plants is sometimes recommended for fields infested with boll weevils. The practice generally results in more harm than good, since it removes a portion of the plants upon which the weevil is most dependent for food during the latter part of the season, and furthermore practically always produces an exceedingly dense foliage growth which greatly reduces the sun control of the weevil stages and promotes such dangerous diseases as boll rot.

*Sweetened Poisons.*—Many attempts have been made to make poisoned substances attractive to the weevils by introducing sweets and other ingredients. Some known sweets, such as honey, have a slight attraction for the weevil, but not enough to assist in practical control. Numerous tests of such sweetened mixtures have been made and it has always been found that, though they may have a slight value, results are far inferior to those which can be obtained by applying dry calcium arsenate under the same conditions.

*Contact Poisons.*—Poisons designed to kill the boll weevil by suffocating them have been proposed. They cannot, of course, be effective against the immature weevils within the cotton fruit. Normally, also, the adult weevils are found inside the bracts of squares, where they cannot be reached by sprays. Numerous chemicals have been found which, if placed directly on the weevil, will cause immediate death, but this does not mean that the chemicals are of the slightest value when applied in the field. In the first place, they are nearly always exceedingly injurious to the cotton plant, and furthermore, when applied to the plant under field conditions, do not come in contact with the weevils sufficiently to kill any appreciable number. In spite of the numerous chemicals tested, not a single contact poison has been found to have any practical value in field use against the weevil.

*Repellents.*—In the same way it has been claimed that numerous chemicals, fumigants, etc., have a repellent value against the boll weevil. Almost every conceivable compound has been tested for this action, and not a single one has been found which had the slightest repellent action against the weevil.

*Other Proposed Remedies.*—Many other remedies have been suggested for the weevil. Literally, hundreds of these have been carefully investigated, and it has been found that the claims of their advocates were based on faulty observations and careless experiments. It is true that many of them when placed directly on the weevil will cause immediate death, but they are still found valueless when used in the field. The claims made at different times of the repellent power of tobacco, castor bean plants, and pepper plants against the boll weevil have no foundation whatever. In fact, none of these plants has the least effect in keeping weevils away from cotton.

**Effect of the Boll Weevil on Cotton Production in the United States.**—The production of cotton increased from 1892, the time

weevils first entered the Cotton Belt, until 1914. Since that time it has decreased considerably. The yield per acre was reduced about 37 per cent, on the average, according to Hinds.<sup>5</sup> The reduction in yield per acre was offset for a time by increased acreage in the states invaded, and by increased acreage and improved cultural methods in regions not yet invaded.

In some respects the boll weevil has been a blessing in disguise to the cotton growers. It has forced them to use better cultural methods in growing cotton, and these are being used on other crops as well. It has caused many to keep more livestock and to grow other crops in addition to cotton, thus following a better-balanced system of agriculture.

#### THE PINK BOLL WORM

The pink boll worm (*Pectinophora gossypiella*, Saunders), was described by Saunders of England in 1842 from specimens sent to him from India, where the insect was observed doing damage in cotton fields. India or southern Asia was probably the original home of the pink boll worm, but it is now found, according to Hunter,<sup>6</sup> in East Africa, West Africa, Egypt, Nigeria, Sudan, Zanzibar, India, Bengal, Ceylon, Burma, China, Philippines (Luzon), Hawaii, Brazil, and Mexico. Specimens have also been found in Texas, Louisiana, and New Mexico, but it is believed that the insect has been eradicated in the regions in the United States where found except in a part of western Texas near the Mexican border.

The pink boll worm was introduced into Egypt in 1906-1907 in cotton sent from India for ginning. It was carried from Egypt to Brazil in cotton seed in 1911-1913 and to Mexico in the same way in 1911. In 1916, 446 car loads of cotton seed were shipped from Mexico to oil mills in eleven different places in Texas. A part of this seed contained pink boll worms, and as a result infestation was started in the region about Hearne and about Beaumont, two of the places that had received seed. Infestation found in other parts of Texas are traceable to other sources.

**Damage.**—The pink boll worm ranks at least second among destructive cotton insects. The larvae enter seeds, eat their kernels, and render them practically valueless. The lint on the infested seeds fails to reach full development, being short and kinky (Fig. 80). A part of or all the locks of many bolls are

practically ruined. Bolls formed early in the season are infested much less than later ones. Gough examined 106,400 bolls in Egypt one season. Infestation varied as follows:

July bolls, less than 10 per cent.

August bolls, 10 to 25 per cent.

September bolls, 25 to 75 per cent.

October bolls, 75 to 89 per cent.

It is estimated that there is a loss of 17 per cent of the Egyptian crop. In Brazil, the estimate of damage runs from 30 to 66 per cent of the crop; in Mexico, in 1917, the estimated damage was from 30 to 50 per cent.



FIG. 80.—Cotton locks showing typical injury by the pink bollworm (*Pectinophora gossypiella*). (After Hunter.)

**Appearance and Life History.**—The pink boll worm is the larval stage of a small dark-brown moth. The different stages of the insect are described by Hunter<sup>6</sup> as follows:

The pink boll worm has four stages, namely, egg, larva, pupa, and adult, or moth. The moth (Fig. 81), resembles somewhat the common clothes moth of this country. From tip to tip of the extended wings it measures from  $\frac{3}{5}$  to  $\frac{4}{5}$  inch. It is of a dark-brown color, the fore wings ending in a rather sharp point. The hind wings are somewhat broader than the fore wings and end in an even sharper point. The eggs are very small objects, somewhat oval, about  $1\frac{1}{25}$  inch long and  $1\frac{1}{50}$  inch broad. The surface is white and finely wrinkled. The larva

(Fig. 81), when first hatched, is glassy white with light-brown anterior markings. It grows rapidly and when mature measures nearly  $\frac{1}{2}$  inch in length. It is cylindrical, white, with the dorsal side strongly colored with pink. The pupa (Fig. 81) is about  $\frac{2}{5}$  inch in length, reddish brown, with the posterior end pointed and ending in a hook-like process.

The small, pink corn worm (*Peroderces rileyi*, Walsingham) is sometimes mistaken for the pink boll worm. It is of much the same size and color and is frequently found in cotton bolls, but it enters only old decaying or diseased bolls. It does not enter perfect seed and does no damage to cotton.



FIG. 81. Pink boll worm; adult, larva, pupa, and egg. (Figure reduced slightly in reproduction but cut shows insects enlarged about two and one-half times.) (After Hunter.)

According to Busck,<sup>10</sup> who has spent considerable time studying the pink boll worm in Mexico and in Hawaii, the female pink boll worm lays eggs singly or in small groups on the green bolls or in the flowers. One moth will lay about 100 eggs. These hatch in from 4 to 12 days. The larva immediately bores its way into the boll and attacks the seed. As soon as the contents of one is eaten, it enters the one next above. As a rule, the larva remains within the lock, but it may drill a hole through to an adjoining lock and enter. It never leaves one boll to attack another. When full grown, the larvae frequently web together two seeds which they have hollowed out, thus making a cell of some size. These double seeds are characteristic of the work of the pink boll worm, and they furnish a quick method of determining whether or not a lot of seed is infected.

The larva develops in 20 to 30 days during the summer, but later in the season the period is considerably longer. Gough reports larvae in Egypt remaining alive in a quiescent condition for over 2 years. Busck found larvae alive in cotton bales 18 months after having been placed in the bales. Following the larval stage is a pupal stage, which lasts 10 to 20 days. The moth which hatches from the pupa lives but a comparatively short time, the majority, according to Busck living only 14 to 20 days.

The pink boll worm has been reported as feeding on several different species of plants, but more recent studies have indicated that it uses only cotton or some closely related species in the same family of plants.

**Control Measures.**—Although the pink boll worm has a number of insect enemies, it appears as if none of them are very troublesome, since they have but little influence as control measures. According to Hunter,<sup>6</sup> the most important one is a small mite, *Pediculoides ventricosus*, Newport.

Since the insect winters in cotton seed, it is possible to fumigate the seed or to sterilize with heat sufficiently great to kill the insect but not destroy the vitality of the seed. Collecting all undeveloped or defective bolls left in the field by the pickers is also an aid in control.

Several indirect methods of control, such as are used in boll-weevil districts, as early varieties, early planting, good culture, etc., are helpful.

As soon as the pink boll worm was found in Texas, the Federal Horticultural Board of the U. S. Department of Agriculture started active operations to eradicate it. A large force of entomologists was assembled and much scouting was done to determine the limits of the infestation. Laborers went over the infested fields and some adjoining ones, collecting and destroying with kerosene all trash and all portions of cotton plants. The cotton picked from the infested fields and nearby ones was also handled so as to prevent any infestation coming from it. The planting of cotton in the areas about the regions where the boll worms were found was prohibited by the governor.

To safeguard against further introduction of the pest into the country, the Department of Agriculture put forth several regulatory measures, some of which were:

1. The exclusion from the United States of cotton seed from all foreign countries except the Imperial Valley of Lower California and exclusion also of seed from Hawaii.
2. Regulation of the entry of cotton seed products from all foreign countries and from Hawaii.
3. Regulation of entry and disinfection of all imported cotton and cotton waste, and also burlaps which have been used as wrappings of foreign cotton, including such material from Hawaii.

#### COTTON INSECTS OF LESSER IMPORTANCE

Although the boll weevil and pink boll worm are the cotton insects that do by far the most damage, there are several others that injure cotton plants more or less which deserve mention. The cotton leaf worm, the southern grass worm, boll worm, red spider, and cotton aphis or louse are the most important of these.

**The Cotton Leaf Worm or Cotton Caterpillar** (*Alabama argillacea*, Hübn).—The cotton leaf worm, also sometimes called army worm, eats leaves, flowers, young bolls, and other tender parts of cotton plants. It probably ranks third among American cotton insects in respect to destructiveness. It has been known in the United States since 1793, and was for a good many years considered a very serious pest on cotton. Its seriousness was largely due to the fact that there were no satisfactory control measures prior to 1871. About that time it was discovered that it could be poisoned effectively by the use of paris green or other arsenical poisons.

Since 1890 the cotton leaf worm has appeared only occasionally, or rather sporadically, but it would have done considerable damage certain years had it not been controlled. As a rule, it has appeared during the latter part of July or during August, so late in the season that it did but little damage, and in many instances was a distinct help in that plants were defoliated and checked in the growth, thus robbing the boll weevil of food the latter part of the season.

The cotton leaf worm is thought to be a native of Central and South America. It probably migrates northward each spring or early in the summer. It flies freely, having been reported some years as far north as Canada.

**Life History.**—The eggs of the cotton leaf worm are deposited singly on the under side of leaves. They are pale green in color and not difficult to distinguish. They hatch in from 3 to 20

days, the time depending on temperature, producing a larva that feeds voraciously on the younger leaves. The larvae (Fig.



FIG. 82.—Cotton leafworm: stages and work. (After Pierce.

82) are about  $1\frac{1}{2}$  inches in length when grown and somewhat varied in coloring, some being yellowish green without prominent

stripes, while others have a black stripe down the back with a fine central yellow stripe. Each segment has four black dots above. The larva when mature webs itself in a leaf rolled up on one side and there pupates. Other larvae frequently eat away the leaf, leaving the pupa (Fig. 82) hanging by a thread. The larval stage lasts from 10 days to 3 weeks. From the pupa there hatches a tawny-colored moth with a wing spread a little more than an inch. The pupal stage lasts from 1 to 4 weeks.

*Control Measures.*—The cotton leaf worm is easily controlled by poisoning with powdered lead arsenate or calcium arsenate. The poison dust is most effective if applied when the plants are moist, and is best applied with dusting machines, such as are used for boll-weevil poisoning, at a rate of 4 or 5 pounds per acre. Another method of applying the poison which is fairly satisfactory is known as the pole-and-bag method. In applying the poison the operator rides a mule between rows of cotton, carrying in front of him a pole about 4 feet long, to each end of which is attached a muslin bag containing poison. The bags are agitated sufficiently as the mule walks along to cause the poison to shake out slowly. By weighing the bags before and after a known area has been covered, the operator may know just how much poison is being applied. Poisons should be applied before defoliation becomes heavy.

**Southern Grass Worm.**—The southern grass worm (*Laphygma frugiperda*, S. and A.) (Fig. 83), also called fall army worm, is another insect which at times does some damage to cotton plants. The larvae appear in numbers and feed on many different plants, including grasses and cultivated plants. They gnaw the stems and eat the growing tips of cotton plants. They enter the ground to pupate.

The southern grass worm may be controlled with poisons. Methods such as are used in poisoning the leaf worm are satisfactory.

**The Cotton Boll Worm.**—The cotton boll worm (*Chloridea obsoleta*, Hübn.) (Fig. 84) destroys cotton squares and bolls by eating their interior. In some localities, especially in Texas, the damage done is considerable. This insect is also known as the corn ear worm and the tomato fruit worm because it attacks corn and tomatoes.

Eggs are laid on leaves. After hatching the young larva feeds on the surface of the leaves for a short time and then enters

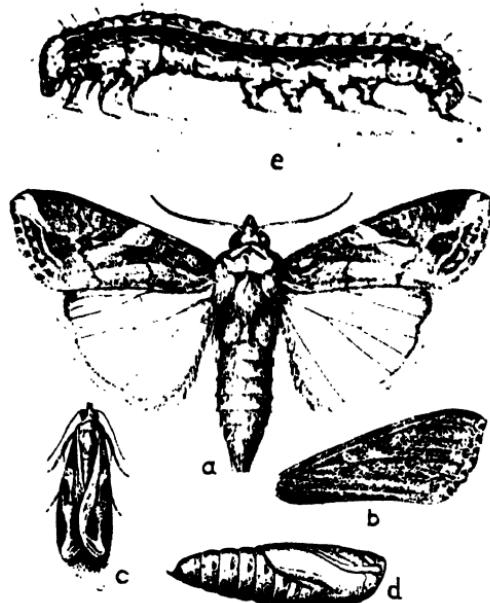


FIG. 83.—Southern grass worm, or fall army worm: (a) Adult male moth; (b) right front wing of female moth; (c) moth in resting position; (d) pupa; (e) full-grown larva. (a, b, d, e, about twice natural size; c, about natural size.) (Walton and Luginbill.)

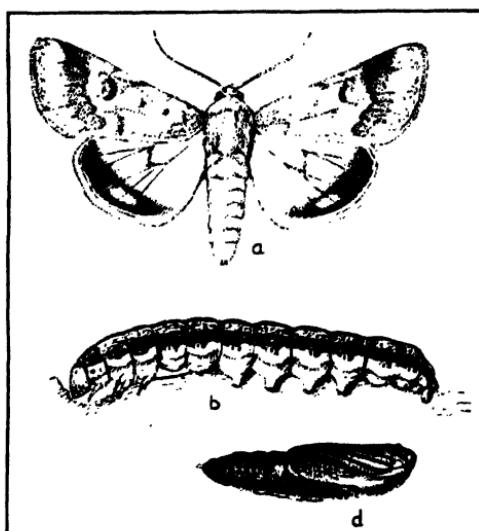


FIG. 84.—Bollworm: (a) moth, or adult; (b) larva, or worm; (d) pupa. About two-thirds natural size. (Howard.)

a square or boll. After destroying the contents, it seeks another, so continuing until several have been ruined. When full grown, it enters the ground to pupate. A moth hatches from the pupa in about 2 weeks. This insect passes the winter as a pupa in the soil.

But little effort is made to control the cotton boll worm. Fall plowing and frequent plowing of growing crops are helpful, as the pupae may be destroyed in the soil. When the attack is serious, poisoning may be resorted to, the same plan being followed as was given for the cotton leaf worm.

**Cotton Square-borer.**—The cotton square-borer (*Uranolites melinus*, Hübn.) (Fig. 85) is described by Pierce<sup>7</sup> as follows:

Frequently, the squares are bored by small, oval, flattened, pea-green, velvety haired larvae, known as square-borers. Each larva can destroy



FIG. 85.—Cotton square-borer: (a) Adult butterfly, top view; (b) same from side, with wings closed; (c) larva, or borer, from side; (d) pupa; a-d, somewhat enlarged. (Howard.)

many squares. The larvae transform into small pupae, and when mature these become the dainty little blue swallow-tailed butterflies so often seen in the cotton fields. It is seldom necessary to take active measures against them.

**Cotton Red Spider.**—The red spider, (*Tetranychus telarius*, L.) on cotton is not a spider, but a small mite (Fig. 86) that attacks cotton, beans, corn, tomatoes, and many other plants both wild and cultivated. It is rather generally distributed throughout the southern states, but it is most prevalent in the eastern states of the group. It is usually brick red in color and about  $\frac{1}{50}$  inch in length, being so small that it is difficult to see it without a magnifying glass. Numbers of them together give the cotton

leaf the appearance of rust, and the disease is sometimes wrongly called rust.

As a rule, red spiders become very numerous only in spots in fields. They rarely spread over more than a few acres, but may do much damage in the area covered. They collect on the under side of cotton leaves, suck juices from them, and cause them to redden, curl up, and fall. The entire plant is frequently killed. McGregor<sup>8</sup> estimated that in South Carolina, in 1912, the loss occasioned by this pest amounted to two-fifths of the crop over an area of 20,000 acres.

Red spiders spread over a field, normally by crawling from plant to plant. The spread is often hastened by rains washing them

from the plants and transporting them some distance. Winds, animals, etc., may also assist in the dispersal. They go through the winter on weeds, such as sow thistle, Jerusalem oak, evening primrose, or the violet—plants that hold their leaves during the winter.

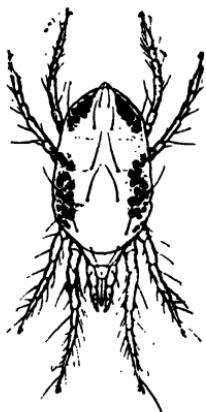


FIG. 86.—The female red spider. Highly magnified. (McGregor and McDonough.)

Since the red spider must have green leaves on which to winter, one important control measure is to destroy such plants as were mentioned above before the winter season. Outbreaks may sometimes be checked in the early stages by pulling up and carefully removing all infested plants and burning them. In case the infestation is widespread and serious, it is advisable to spray. Several sprays are satisfactory. Potassium sulphide (1 ounce to 2 gallons of water), lime-sulphur (homemade or commercial), and kerosene emulsion (prepared according to the usual formula) are recommended by McGregor.<sup>8</sup> Dusting with finely powdered flowers of sulphur is also a good control measure. To be effective the spraying must be done with extreme care. The material must reach the under side of leaves, and a second application must be made a week after the first in order to kill the spiders that were in the egg stage when the first application was made.

**Cotton Aphis or Cotton Louse.**—The small green lice, or Aphids (*Aphis gossypii*, Glover) (Fig. 87), found on the lower surface of cotton leaves are known to every cotton planter. They are very minute in size, but because of their extraordinary rate of

reproduction they sometimes do considerable damage. Were it not for insect enemies which prey upon the lice, they would do enormous damage. They suck the juices from the leaves, causing a curling or dwarfing of the leaves and sometimes death. Young plants, during cool weather, are frequently damaged considerably. The writer has observed that plant lice, during the past few years, have been very numerous on cotton which has been poisoned with calcium arsenate to control boll weevils. They caused the shedding of leaves and the blackening of the entire plant, including the surface of the lint cotton in open bolls. The blackening is apparently due to a mold that grows on the honeydew excreted by the lice. The poison is thought to kill the ladybug beetles and perhaps other insects which hold the

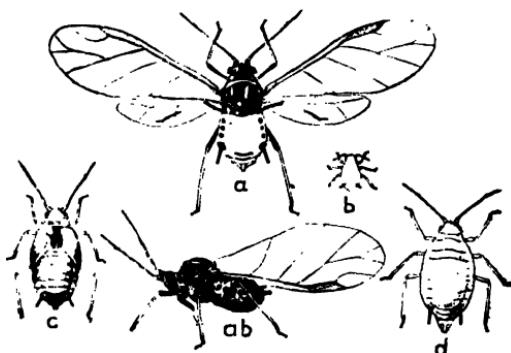


FIG. 87.—Cotton aphis: (a) winged female; (ab) dark female, side view; (b) young nymph, or larva; (c) last stage of nymph; (d) wingless female. All much enlarged. (Chittenden.)

plant lice in check. Spraying with 40 per cent nicotine sulphate,  $\frac{3}{4}$  pound to 100 gallons of water, will control the lice, but is expensive. It has been found also that the insect may be controlled by mixing 5 pounds of Black Leaf 40 with 95 pounds of calcium arsenate when dusting for boll weevils.

**Cotton Stainer.**—The cotton stainer (*Dysdercus suturellus*, H. Schf.) does damage in the southeastern part of the United States and in Egypt. It is a reddish bug (Fig. 88) with a long beak, which it uses in sucking juices from different plants. It damages cotton by sucking juice from squares and bolls, but the chief injury results from the staining of lint. This is done by the excrement from the insects and by the juices from their bodies when they are crushed in the picking or ginning process.

The cotton stainer passes the winter in the adult stage on weeds or old cotton stalks about the cotton fields. Control measures consist in burning old cotton stalks or other trash in which they may have taken refuge during the winter, or in trapping them with bunches of cotton seed placed about the field. After the bugs have taken refuge in these bunches, they may be collected and treated with hot water to destroy the insects.

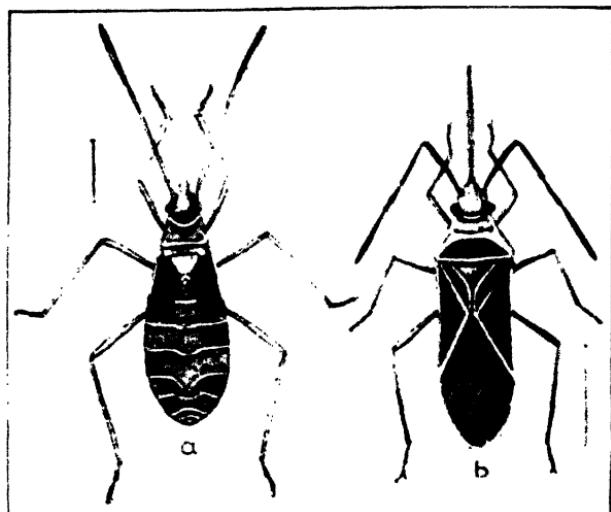


FIG. 88.—Cotton stainer: *a*, fourth-stage nymph, or pupa; *b*, adult. *1* enlarged 1 to 6.

**Cotton Wire Worms.**—The larvae of different species of click beetles (*Monocrepidius resupinus*, Fabricius, and other species commonly known as wire worms, feed on the roots of cotton plants and do considerable damage. They are mentioned by Pierce<sup>7</sup> as being especially troublesome in South Carolina. They are best controlled by a crop rotation, in which a small grain crop followed by cowpeas or some other legume is included.

**The Cotton Hopper.**—The cotton hopper, or cotton flea (*Psallus seriatus*), is another cotton insect that is thought to have injured cotton plants in certain localities recently. The insect is a small green bug, not more than  $\frac{1}{10}$  inch in length. Plants affected by the disease thought to be caused by the cotton hopper shed very small squares in large numbers, become abnormally tall, and have but poorly developed fruit branches. Very few bolls are produced. The trouble has been most marked in

the coast counties of Texas but has been observed in other parts of Texas and in other states. It is probable that the causal insect is to be found in most parts of the Cotton Belt, but for some reason the injury has not been extensive in most regions. From studies that he has made, Dr. W. D. Hunter of the Bureau of Entomology, U. S. Department of Agriculture is of the opinion the actual damage done plants is not due to the punctures made but to a virus injected by the insect and that the malady is in the nature of a mosaic disease.

While the life history and habits of the cotton hopper have not been worked out fully, it has been observed that in south Texas the insect appears on the weed known as horsemint in the spring. About the end of April it migrates to the cotton plant. During July it migrates to Croton, or goatweed, plants.

Various insecticides have been tried on the cotton hopper. Superfine dusting sulphur is probably the best. Ordinary flowers of sulphur may be used. Weekly applications are sufficient; 8 to 10 pounds per acre are needed. The dust may be applied with the machinery used in dusting for boll-weevil control.

**Corn-root Aphis.**—The aphis which frequently attacks corn roots (*Aphis maidiradicis*, Forbes) is sometimes found on the tap root of cotton. A 3-year rotation consisting of corn, cotton, oats, and cowpeas is a satisfactory control measure.

**Miscellaneous Insects.**—Several other insects feed on or live about cotton plants and do more or less damage. Among these may be mentioned cutworms, which burrow into the soil during the day and then come out at night and cut off young plants; May beetles, which in the adult stage attack young cotton plants; grasshoppers, which eat cotton leaves rather seriously in Texas and occasionally in other regions; cotton bugs (several different species of sucking bugs, "squash" bugs, "stink" bugs, "plant" bugs, etc.), which attack cotton squares and bolls; flower beetles, frequently found in blooms of cotton, sometimes eating petals, stamens, and pistils; moth stalk-borer, a caterpillar which tunnels through the heart of cotton stalks; snowy tree cricket, which makes egg puncture in stems; sharpshooters, which puncture stalks and lay eggs in leaves; ants, which destroy some boll-weevil larvae but are harmful in that they assist harmful aphids; ladybug beetles, both the larvae and adults of which feed on aphids and are very helpful in holding them in check; and many parasites that prey on other insects mentioned.

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## CHAPTER XVI

### COTTON HARVESTING

Cotton harvesting, or "picking," as it is commonly termed, is the most expensive single operation connected with the production of cotton. At present, cotton is picked by hand, a boll at a time. This makes the harvesting slow, tedious, and expensive. The difficulty of getting cotton picked is the chief limiting factor in the production of cotton in many regions. This is especially true in sections of the American Cotton Belt where labor is scarce, or in sparsely settled regions of the world, such as parts of South America and Africa. No doubt, in the future, satisfactory mechanical cotton pickers will be made. Although a number have been invented, there are none in common use today.

**Cost of Harvesting.**—Since cotton is picked by hand almost altogether, the cost of harvesting is governed largely by the wages paid day laborers in the particular region. The wages paid vary considerably in different localities, usually being higher near towns or cities, or near regions where there are factories, saw mills, etc. If the market value of the lint cotton is good, the growers can afford to pay more for picking, and do so in order to save as much of their cotton as possible, and to get it out early that the grade may be good. If labor is scarce, the competition for pickers is greater and consequently higher wages are paid. Wages paid during the first part of the season while the cotton is green and heavy, and has not yet been picked over, are lower than later in the season after the seed cotton has become lighter in weight, the bolls less plentiful and harder to pick free from hulls and trash.

In the United States prior to the World War, the value of cotton was low, much of the time being worth less than 10 cents a pound. During that time the price paid for picking was usually from 40 to 60 cents for 100 pounds of seed cotton. Since the war, cotton values have been considerably better. The price paid for picking has been from 75 cents to a \$1.25 per hundred during the first part of the season and, in some localities, \$2 or more during

the latter part. During the latter part of the season, the days are shorter, bolls less plentiful, burs rotten, the weather disagreeable, and the ground often wet or muddy. It is worth considerable more to pick cotton under such conditions.

**Time of Harvesting.**—The time for beginning cotton picking varies somewhat with the season, being as much as two weeks earlier some years than others, and varies much with the latitude. In southern Texas picking begins about the first of August and continues until the crop is all gathered, which is usually in November or December. In states farther to the north the date for beginning picking is successively later until the most northern states, which do not begin picking until late in September, are reached.

The date picking is begun depends to some extent, also, on the variety grown. The bolls of some of the large-boll varieties do not open quite so early as the bolls of some of the early small-boll varieties. Hot, dry weather during July and August may cause cotton plants to check their vegetative growth and open their bolls prematurely. The defoliation of plants by insects may also cause premature opening of bolls. While this is, of course, not desirable, since the cotton from the prematurely opened bolls is not of good quality, it does advance picking dates.

In the southern part of the Cotton Belt, cotton picking is usually finished in November or early in December. In the most northern states of the belt there is usually cotton in the fields to pick after Christmas, and if the crop is heavy and the weather during the fall and winter unsatisfactory for picking, there may still be some cotton yet in the fields at plowing time in the spring.

**Picking Cotton by Hand.**—A person must have considerable skill at the work to be a good cotton picker. He must be able to get his hands on the bolls quickly, remove the cotton from the whole boll in one or two quick grasps, and avoid getting an excessive amount of dead leaves and trash in the seed cotton. Picking cotton is very tiresome work for inexperienced persons— and they do not get much cotton picked either. In picking, it is necessary to stoop or bend over almost continuously for the greater part of the day. Early in the season the weather is much too hot for comfort, and late in the season it is too cold— pickers suffer with cold fingers. Dragging or carrying a heavy bag of cotton is tiring also.

Much of the cotton in America is picked by negro women and children. They are trained from childhood, become skilful, and so accustomed to the work—perhaps have their muscles hardened to it—that they do not complain of being tired. They usually work together in small groups, gossip, joke, sing, and apparently have a good social time. The negro men do not like to pick cotton as well as the women, and since on most plantations there is other heavier work to do the men are relieved from a part of the picking. If the family tends a few acres as their special crop, the men in the family usually help pick.



FIG. 89.—Picking cotton by hand in Mississippi.

In certain sections of the South there are many white tenant farmers whose families work in the fields and pick cotton. The white people usually work more energetically and are more concerned about getting their work completed. In Texas and in some border states Mexicans are brought in to pick cotton. In parts of the Southwest, Indians do considerable cotton picking.

When picking, the picker carries a long sack (see Fig. 89), which is held in place by a strap over the shoulder. The sack has a wide opening at a place convenient to be reached by the right hand. The lower end of the long sack drags on the ground. This

relieves the picker of the necessity of supporting the weight of the cotton while picking. The bag is dragged down the row as the picker moves from plant to plant. A bag containing 50 to 75 pounds of cotton may thus be handled with reasonable ease.

The amount of cotton that a picker can gather in a day depends on several factors—skill and energy, the abundance of open cotton bolls, size of the bolls, the picking qualities of the variety, etc. For average cotton, 100 pounds a day is a fair day's work, especially when this amount is picked day after day during the picking season. In good-picking cotton, where bolls are very plentiful, considerably more than this has been picked by some pickers. Some persons have picked as much as 500 pounds in a day. When an effort is made to pick such a large quantity some cotton is left on each stalk and much trash is gathered with the cotton. Such rapid picking is, therefore, not satisfactory.

**Picking the Crop Grown.**—It is sometimes estimated, on the basis of the size of the rural population of the South, that a crop of 40,000,000 bales could be picked. These estimators have not had much experience in cotton fields, as a rule, and leave out of consideration several factors. They base their estimates on picking weights obtained under the most favorable conditions, and on everybody picking cotton every day. As a matter of fact, more than half of the rural people do no picking. A good average picker will not average more than 100 pounds a day. Since the women do not pick cotton on Saturday or Sunday, that leaves only 22 or 23 days in the month for picking. An allowance of 7 or 8 days a month for bad weather, sickness of picker or some member of the family, attendance on funerals in the neighborhood, etc. leaves only 15 days for work. This means a bale a month and, as the season lasts about 3 months, three bales per picker for the steady pickers. Under the conditions prevailing at present, any great increase in amount of cotton produced would entail some difficulty in getting the crop harvested.

**Picking American-Egyptian and Sea Island Cotton.**—American-Egyptian and Sea Island cotton have a long, silky staple and are used for making fine fabrics. They must be picked and ginned very carefully to be satisfactory. The grower cannot obtain a commensurate price for a low grade.

These cottons are hard to pick. It was thought for a while that the expense of picking the American-Egyptian cotton was

going to be so great that it would prevent its cultivation. The bolls are small, not easily handled, and must be picked free from trash. It has been found, however, that a laborer can pick about half as much of this cotton as of Upland varieties, and if paid twice as much per hundred he is satisfied.

Sea Island cotton is picked even more carefully than Egyptian. After it is picked, it is gone over by hand and leaves, trash, and defective locks removed. It is dried in the sun for a day or two and then stored in bins for 5 or 6 weeks before ginning.

**Picking Bolly Cotton.**—In the northern part of the Cotton Belt frosts commonly come in the fall before a portion of the bolls on the cotton plants have opened. These frost-bitten bolls contain cotton of inferior quality, but it is of some value. The unopened bolls are gathered and put through a gin with a huller attachment which bursts the bolls and removes the hulls. The lint ginned from such bolls is known as "bolly cotton."

**Cotton Picking in Foreign Countries.**—In several of the foreign countries where cotton is grown, such as China, India, and Egypt, labor is very abundant and there is no trouble in getting cotton picked. In China it is a common practice to gather the unopened bolls, store them, and pick out the seed cotton by hand after they have opened. This practice entails extra labor, but it gives an excellent grade of staple, since the lint is not exposed to the weather and is relatively free from leaf fragments and trash. In Egypt much care is exercised in picking cotton in order to produce staple that will grade high, but in India this does not seem to be the case. Much of the cotton there is of a very low grade.

**Mechanical Cotton Pickers.**—It has been the hope of cotton growers for many years that a machine would be made to pick cotton. Inventors have labored over the problem and devised a score or more machines. All of these pick more or less cotton, but not enough to make them an economic success.

It is a difficult matter to devise a machine to pick cotton, for several reasons. The cotton bolls do not all open at the same time. The first ones that open must be picked before later ones open to prevent the staple of the early ones from being damaged by exposure to the weather. The plants and late bolls must not be injured while gathering the early bolls. The seed cotton must be picked with a minimum of trash and leaf fragments.

The bolls are high and low on plants and distributed throughout a considerable extent of space. Some bolls do not open well. The machine must gather the cotton cheaper and more rapidly than it can be picked by hand. One writer has said that making a machine to pick cotton is much like devising a machine to pick strawberries or raspberries. The machine must be so constructed that it will get all of the berries but it must not mash any of them.

Notwithstanding the difficulty of the problem, it seems reasonably certain that some sort of a mechanical cotton picker will be perfected in the near future which will pick at least a part of the cotton and be of economic value, especially under favorable conditions, in regions where labor is scarce.

The machines that have been devised are of three types - the vacuum-suction type, the mechanical-finger type, and the whirling spindle type.

*Vacuum Type of Mechanical Cotton Pickers.*—The pickers of the vacuum type are not altogether mechanical because it is necessary for the operator to touch each cotton boll with a suction nozzle. This type of machine is simple in construction. It consists of a small engine, mounted on a truck, and so connected that it drives a fan which draws the seed cotton through a tube, or set of tubes, into a hopper. Several smaller tubes are joined to the large ones. The operator touches the tip of the open boll and the seed cotton is quickly sucked in and carried to the storage receptacle. Some of the machines of this type have a nozzle on the end of the tube which contains revolving brushes, wheels, or some sort of mechanical device to catch the exposed cotton and assist in pulling it from the boll. This may remove from the bolls cotton that the simple suction would not remove.

Illustrations of the suction type of mechanical cotton pickers are to be found in the Worswick-Haardt cotton picker, invented by J. E. Worswick, Montgomery, Ala.; the Thurman vacuum cotton harvester, invented by John S. Thurman, and manufactured by the Vacuum Cotton Harvester Company of St. Louis, Mo.; and the Indiana (Stukenborg) electric cotton picker, invented by L. C. Stukenborg of Little Rock, Ark., and manufactured by the Indiana Silo and Tractor Company, Anderson, Ind. The last-mentioned machine has nozzle attachments at the end of the tubes, and is illustrated in Fig. 90.

Objections that have been raised against the vacuum type of pickers are that they are expensive, that there is much hand labor involved in moving the nozzle to each boll, and that the suction draws in an extra amount of foreign matter.

*Mechanical-finger Type of Cotton Pickers.*—The second type of cotton pickers mentioned above is designated as the mechanical-finger type, because the essential part of the machines consists of rapidly moving fingers, covered with hooks or teeth, which quickly pull the cotton from the open boll (see Fig. 91). The nozzle containing the fingers must be moved by the operator

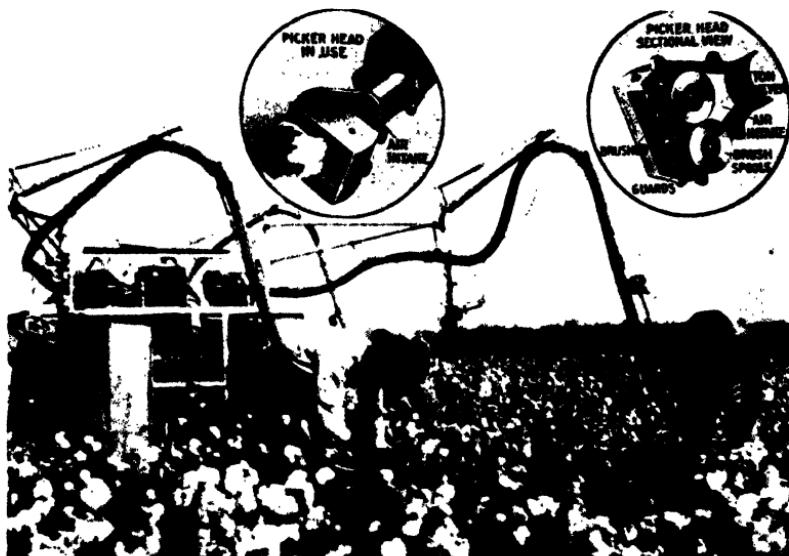


FIG. 90.—Indiana (Stukenborg) electric cotton picker in use. (Courtesy Indiana Silo Company.)

to each boll that is picked. From the nozzle the cotton is carried by a series of conveying teeth through the barrel of the machine and automatically discharged into a funnel-shaped canvas sack which is attached to the back end of the machine. The fingers are driven by a small electric motor attached to the machine. Power is furnished by a small power plant drawn along the cotton row by a mule.

The Staso mechanical cotton picker manufactured by the Central Commercial Company, of Chicago, Ill., is an illustration of the type of picker just described.

The Lowry cotton picker, invented by George A. Lowry, of Boston Mass., works on much the same principle, but is constructed differently.

Objections similar to the ones raised against the vacuum type of picker are made against the mechanical-finger type.

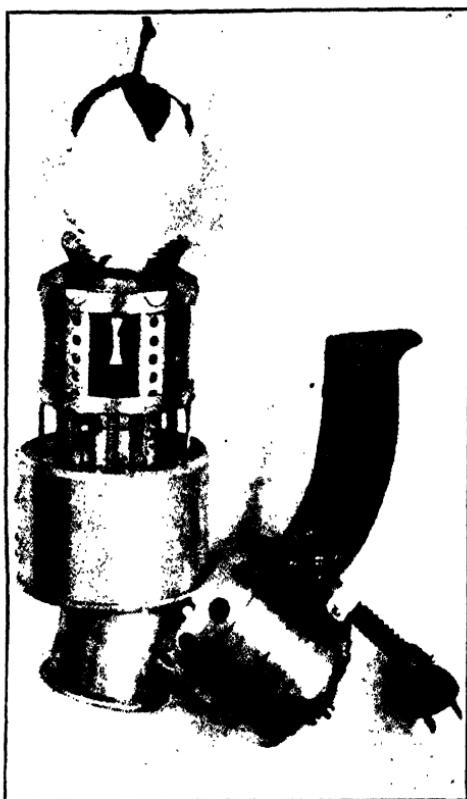


FIG. 91.—Staso mechanical cotton picker. (Courtesy Staso Mechanical Cotton Picker Company.)

*Whirling-spindle Type of Cotton Pickers.*—Mechanical pickers of the third, or whirling-spindle, type are altogether automatic. The machine is driven straddle of a row, and numerous whirling, needle-like spindles move through the cotton plant as the machine passes over it. When a spindle touches a lock of cotton, the lint clings to it and becomes twisted around it in such a way as to draw the cotton from the boll. After the spindles move out of

the plant, the cotton is stripped from them by mechanical means and carried to a container.

The Berry cotton picker is a machine of the type just mentioned (see Figs. 92 and 93). It is a recent invention by H. N. Berry, of Greenville, Miss., and contains a number of improvements over other machines of this type that have been constructed. It has been demonstrated that this machine will pick cotton rapidly, get most of the open bolls, collect very little, if any, more trash than a person picking by hand, and damage

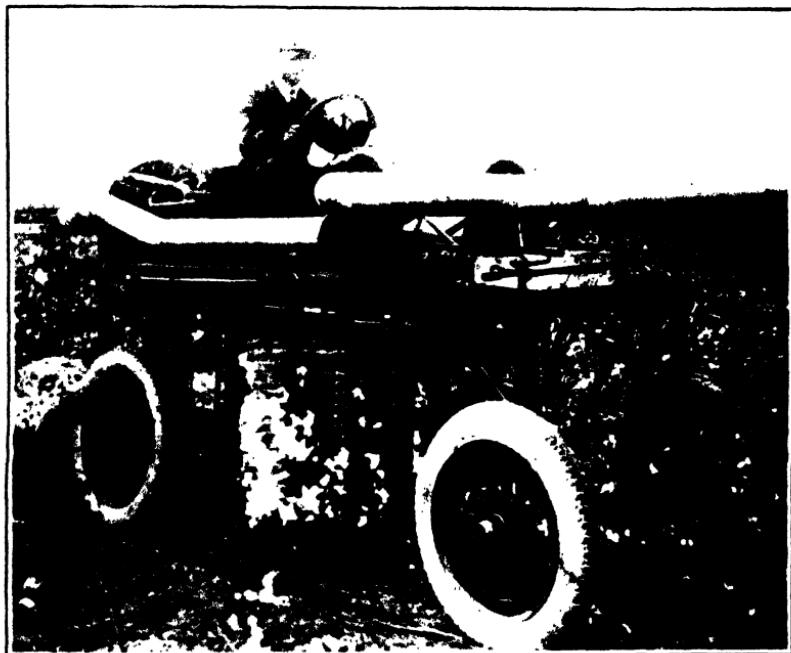


FIG. 92.—Berry cotton picker with wire screen and part of suction pipes removed to show cylinders with picker spindles. (Courtesy H. N. Berry.)

plants but very little. It may be driven at a rate of 5 miles an hour picking a row as it goes. It has picked a bale of cotton in 3 hours. One man can operate the machine. It occurs to the writer that this machine or one of similar type will be a success and will probably do much to revolutionize cotton growing. On account of its apparent value, space is taken to describe the machine in some detail.

The picking and power mechanism of the Berry cotton picker is mounted on an arched framework supported by four wheels

similar to heavy automobile wheels. The arched framework permits the picker to straddle the row of cotton that is to be picked (see Fig. 92). The machine is driven by a four-cylinder motor similar to the motor used in a light truck. This engine furnishes motive power for propelling the machine and also power for driving the picking mechanism.

The picking mechanism consists of two cylindrical revolving drums which are 12 inches in diameter, and about 3 feet long. Each drum contains more than 500 radiating, whirling steel

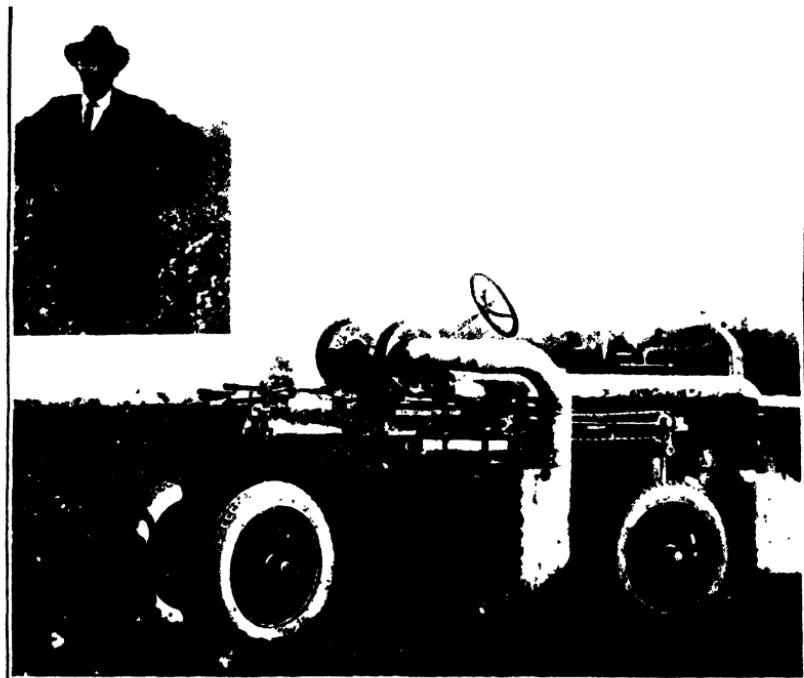


FIG. 93.—Berry cotton picker complete. Insert, H. N. Berry, inventor.

needles. The drums are between front and rear wheels, one on each side of the row, and near enough together that the tips of the radiating needles almost meet in the center of the plant that is being picked (see Fig. 92). The distance of the drums from the ground is regulated by changing the height of the rear wheels in respect to the arch. The radiating steel needles are tapering in shape, about  $\frac{1}{4}$  inch in diameter and 9 inches long. The drums are geared directly with the driving mechanism which turns the traction wheels, so that, as the machine moves forward, the drum

revolves into the center of the plant at the same speed. Thus the needle remains almost stationary in the plant, in respect to movement in line with the row of cotton, and so avoids damage to the plants. While the needles are within the plant, they whirl on their own axis at a rate of about 600 revolutions per minute. If a lock of cotton comes in contact with one of these whirling needles, the loose fibers are immediately firmly twisted around the needle and the lock drawn from the boll. Since a large part of the needles move through the space within the limits of a single plant, and since the limbs and bolls of the plant move to some extent, there is not much chance for a boll to be missed. After the needles have passed through the space within the plant, they stop whirling for a moment, then start whirling in the opposite direction. This tends to unwind the lint that is wound around the needles and facilitates the removal of the locks of cotton. Each needle passes through an aperture in a movable bar which serves as a stripper. As the needle is unwinding the lint about it, the bar moves outward so as to push the cotton from the needle. The movement of the stripper bars is controlled by eccentric tracks above and below each drum. After being dropped by the needle, the cotton is picked up by air blast and carried to a receptacle in the rear of the machine.

## CHAPTER XVII

### COTTON GINNING

Before cotton fibers can be used in spinning or making cloth, or even before they can be marketed advantageously, they must be removed from the seed by some kind of ginning process. During early times, and even as late as 1793, the date of the invention of the saw gin, a considerable quantity of lint cotton was picked from the seed, or ginned, by hand. This was a very slow and laborious process, but enough lint could be secured by a family in this way, by their working at idle times, to supply the needs of the home. During pioneer days it was the custom in many homes to do this work while the family were seated around the fireside in the evening.

**“Churka” Gin of India.**—The first recorded gin made was the small roller gin, or “churka” gin, used in India many centuries ago. This machine consisted simply of two upright pieces of wood, made secure at the base in some way, between which were two small, horizontal, parallel wooden rollers so adjusted that they almost touched (see Fig. 94). Attached to one of the rollers was a hand crank, by means of which the rollers were turned. The seed cotton was fed between the rollers by hand. The lint was caught by the rollers and drawn between them and thus separated from the seeds, which would not pass between the rollers. This type of gin will not work well except with the smooth-seeded varieties like Sea Island. Five pounds of lint cotton was a fair day's work with one of these primitive gins. They are still used to a limited extent in China and India.

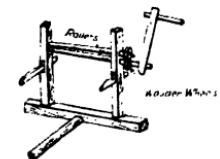


FIG. 94.—Churka cotton gin.

Some of the primitive gins of a slightly different construction had fluted wooden rollers, and others had one small iron roller and a larger wooden roller.

**Roller Gins.**—A number of different kinds of roller gins were made prior to 1793. These were improvements over the primitive

roller gin of India, but were fashioned after it. None of them proved to be of great economic value. According to Miller,<sup>1</sup> the following persons invented improved gins: Krebs, of Mississippi, in 1772; Burden, of South Carolina, in 1777; Eve, of Augusta, Ga., in 1790; and Pottle, of Georgia.

The first roller gins were driven by hand power. Later ones made use of horsepower or water power. The present-day gins use, of course, steam, gas, or electric power.



FIG. 95.—A typical 20-stand roller gin. Lint is shown coming over the rollers and brushes and falling to the floor. (After Townsend.)

The modern roller gin is small and simple in construction. The essential parts consist of a roller covered with leather—walrus hide being preferred, or some other covering which is firm and of such texture that cotton fibers will cling to it freely—and a large knife. The knife is set so that its edge is parallel to the surface of the roller and barely touches it. The locks of seed cotton fall or are fed by hand on one side of the roller, which

picks them up and carries them to the knife. The lint clinging to the roller passes under the knife and is stripped from the seed, which cannot pass under the knife. The lint falls on one side of the roller and the seed on the other (see Fig. 95). Some of the more recent types of roller gins have a mechanical feeder, a contrivance by means of which the seed cotton is carried to the roller regularly and in small bunches. Some also have an extra roller, and an agitator for moving locks and partially ginned seeds.

Roller gins are used in America for ginning Sea Island and American-Egyptian cotton. They are used in Egypt exclusively, and to a limited extent in India and China. Roller gins are considered better than saw gins for ginning cotton with very long staple. The saws may cut the fiber. Objections sometimes made to roller gins are that the lint that comes from them is so packed or wadded up in parts that it makes a poor sample, and makes nep, which bother in spinning; that the lint contains too many pieces of broken seed (true if the gin is not adjusted and run properly); and that the ginning is slow and expensive. A single gin will yield 50 to 80 pounds of lint cotton per hour.

**Saw Gins.**—Prior to 1793, it had been demonstrated conclusively that cotton could be grown easily in the South. England needed cotton, but did not want it in the form of seed cotton, because she had no good means of separating lint and seed. The South had plenty of fertile land and labor and needed a profitable crop to grow. Great need for a machine that would separate the fiber from the seed quickly and economically was therefore felt. It is true that some crude cotton gins had been made, but they were not satisfactory.

**Eli Whitney.**—As is often stated, “necessity is the mother of invention.” The great need for a machine that would separate lint cotton from the seed rapidly and thoroughly stimulated thought which led to the construction of the saw gin by Eli Whitney, a machine that will do more than the early cotton growers imagined a machine could ever do.

Eli Whitney was born at Westboro, Mass., in 1765, and graduated from Yale University in 1792. He possessed much skill in the use of tools, being what is termed “a natural-born mechanic.” It is related by Scherer<sup>2</sup> that at the age of twelve he took his father’s watch to pieces but possessed enough

ingenuity to put it together again, his father being none the wiser.

After graduation from college, young Whitney accepted a position as teacher in a school in South Carolina. Coming South on a boat, he chanced to become acquainted with Mrs. Green, widow of General Nathaniel Green of Revolutionary fame. Mrs. Green became interested in Whitney and invited him to visit her plantation near Savannah, Ga. While there he saw negroes picking lint cotton from the seeds with their fingers and he also heard certain visitors at the plantation, who were promi-

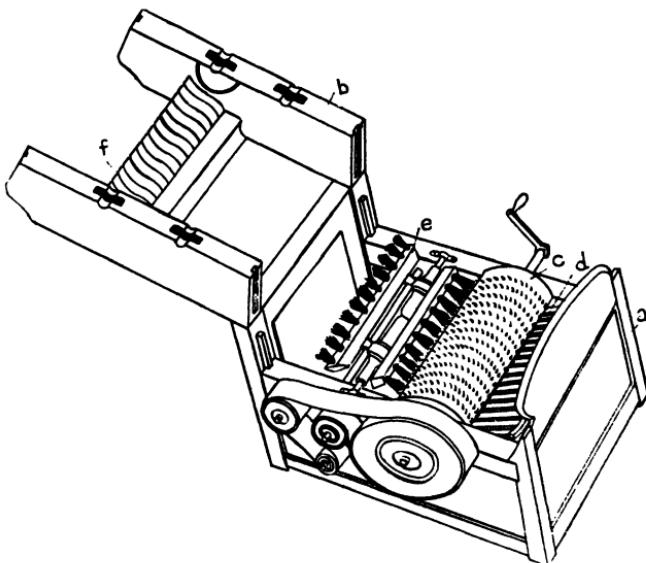


FIG. 96. Original model of Whitney's cotton gin. (After Tompkins)

inent men of the South, mention the great need of a machine that would gin the Green Seed cotton, which was the short-staple cotton with fuzzy seeds and which produced considerably more cotton than the smooth-, or black-seeded, sort like Sea Island.

Whitney at once became interested in the problem and fitted up a workshop in the basement of Mrs. Green's house, where, working with only the plantation tools available, he constructed the first model of his gin in 10 days. First he placed small, sharp hooks over the surface of a board and drew unginned cotton over them. From this came the idea of making a wooden cylinder with hooks attached. With the addition of another revolving

cylinder, to which were attached brushes for pushing the cotton from the hooks, the gin was essentially complete.

The first model of the gin was so promising that Phineas Miller, manager of the plantation belonging to the Green estate, became much interested and agreed to furnish the money needed to perfect this new invention and to put it on the market. In May, 1793, Whitney returned to New England, where he secured better tools and materials to complete his machine. On June 20, 1793, he applied for a patent, which was granted him on Mar. 14, 1794. George Washington, then president, signed the papers (see Fig. 96).

The model presented contained a wooden roller into which were driven spikes. The spikes were bent and sharpened to form hooks. Seed cotton was placed in a hopper, or gin breast as it is now called, in contact with the roller containing spikes. As the cylinder turned, the hooks passed between strips of iron at the back of the hopper. These strips were so placed that the hooks would pass between them in their circuit, carrying some lint cotton which they had engaged in their movement through the hopper but too close to permit cotton seeds to pass. The lint was in this way pulled from the seeds. Just back of the roller containing spikes was another roller, to which were attached four strips of brushes (see Fig. 96). This roller was set so that the brushes would remove the lint from the hooks, being geared to revolve in the opposite direction from that of the hooks and considerably faster. Although revolving in the opposite direction, the two cylinders moved in the same direction where they came in contact.

**An Improved Saw Gin.**—In May, 1796, just two years after Whitney obtained his patent, Hogden Holmes, of Augusta, Ga., obtained a patent on an improved cotton gin. The improvement over Whitney's gin consisted in the substitution of circular saws for the rows of hooks. This was really an important improvement and one for which Holmes deserved credit, although but little has been given him.

Antagonism at once sprang up between Whitney and Holmes. Whitney became involved in much litigation with Holmes and others in defense of his patent rights. Eventually, South Carolina voted Whitney a royalty of \$50,000 for his invention; North Carolina gave about \$30,000; and Tennessee about \$10,000. Most of this money was expended in lawsuits.

**Whitney's Business Policies.**—It was Whitney's plan to maintain a monopoly of cotton ginning. He refused to sell his gins, but built them at various places and asked a toll of 1 pound of lint cotton out of every 3 ginned. Where gins were built by others, Whitney sought to levy a tax of \$200 on each gin. These methods of securing remuneration for his invention were not popular with the cotton growers and brought him into disfavor in the eyes of many, although he was really a benefactor of the public and deserved honor and financial reward.



FIG. 97.—Eli Whitney, inventor of the cotton gin.

**Value of the Cotton Gin.**—The following paragraph taken from an address made by Judge Johnson, of South Carolina, in the lawsuit brought by Whitney and Miller to recover from the state of South Carolina \$50,000 appropriated by the legislature for the purchase of the right to use the gin in the state gives a good picture of conditions in the South at the time the cotton gin was invented and its beneficial effects.

The whole interior of the southern states was languishing, and its inhabitants emigrating for want of some object to engage their attention and employ their industry, when the invention of his machine at once

opened views to them which set the whole country in motion. From childhood to age it has presented to us a lucrative employment. Individuals who were depressed with poverty and sunk in idleness have suddenly risen in wealth and respectability. Our debts have been paid, our capital has increased, and our lands have trebled in value. We cannot express the weight of obligation which the country owes to this invention; the extent of it cannot be seen.

**Improvements in the Saw Gin.**—It was at once very evident that the circular saw as designed by Holmes was an improvement over the spiked cylinder of Whitney, and it was used, even by Whitney. Gins have been enlarged and adapted to the use of horse, water, or other power, but the essential principles of the



FIG. 98.—Old plantation gin house and screw. (*After Tompkins.*)

machine have remained the same even to this day. The large amount of machinery found in modern ginneries is used largely to clean seed cotton, carry it to the saws, and convey the lint cotton away from the saws.

**Old-time Plantation Gin House and Screw Press.**—Before the Civil War a gin house, with a screw press baling for cotton, was a familiar sight on nearly every large plantation in the South (see Fig. 98). The ginning was done during the winter or at times when there was no work to do in the fields. At such times there was plenty of labor available, both man and mule. The plantation manager even had trouble in finding jobs enough to keep his hands employed during the off season of the year;

consequently there was little need or desire for labor-saving contrivances about the gin. The seed cotton was carried to the gin by hand and fed into the gin by hand, and the lint was carried from the gin to the press in baskets, emptied into the press box and tramped down by men, and so on.

Power to drive the gin and to turn the press screw was furnished by mules. Two mules were hitched to each of two large levers which were fastened to a large vertical wooden shaft. This shaft bore a large wooden cog wheel which engaged another wooden cog wheel on a horizontal shaft. A belt running from the horizontal shaft to the gin carried the motive power (see Fig. 98).

When sufficient lint cotton had been packed in the press box by tramping to make a bale, pressure was applied by means of the large wooden screw above the box (see Fig. 98). The screw was raised and lowered by large levers to which mules were hitched. The bale was covered with jute or gunny sack and bound with two hemp ropes.

**The Modern Saw Gin.**—Modern saw gins contrast greatly with the gin just described. In them every known contrivance is used to avoid hand labor. Electric, steam, or gas engines furnish motive power. The seed cotton is drawn out of the grower's wagon bed by suction, and carried mechanically through cleaner, distributor, and feeders to the saws. From the saws the seed is carried by mechanical conveyors to the grower's wagon, a railway car, or a storage bin. The lint is carried by current of air to condensers, which condense it and drop it into the press box. There it is packed by mechanical trampers and pressed into a bale by hydraulic or other power. About all that has to be done by hand is to place the bagging and ties that are to cover the bale in the press box, fasten the ties, and roll out the bale of cotton.

Modern ginneries contain from two to eight gins, or gin stands as they are commonly called (Fig. 99). Where there are more than four stands, they are arranged in two rows, commonly parallel. The smaller gins are mostly private gins and are found on plantations, while the larger ones are chiefly public gins.

**Elevators.**—As was mentioned previously, at modern ginneries the seed cotton is drawn by pneumatic elevators from the wagon which hauled it to the gin. These are made of heavy sheet metal and are in the form of tubes 10 to 12 inches in diameter; the outer

two joints are movable and telescopic, so that different parts of a wagon bed may be reached. Properly connected tubes carry the seed cotton onward to bins, distributor, cleaner, or feeder, just as desired. The suction is produced by rapidly revolving fans so placed as to draw the air through the tubes.

*Cleaner and Separator.*—In most gins, the seed cotton from the wagon is first carried to a cleaner or separator (Fig. 99). Here the cotton is first thrown forcibly against a wire screen; part of the sand and dirt contained passes through the screen and is thus separated from the cotton. The cotton is next taken up by

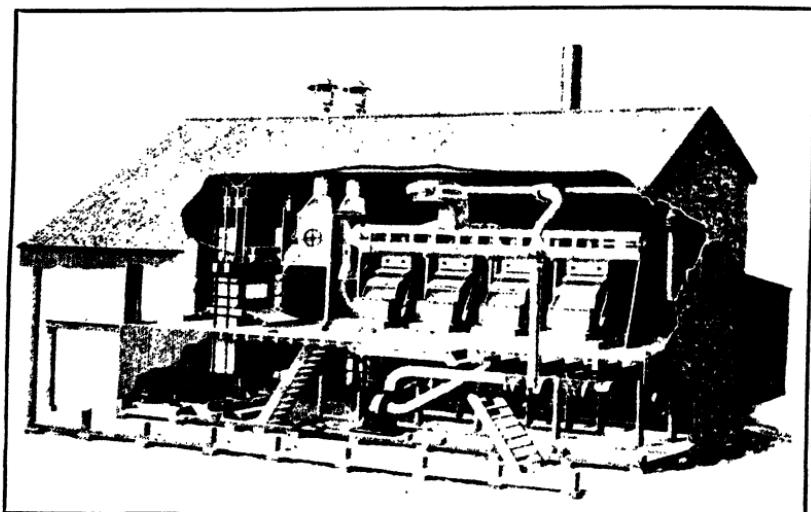


FIG. 99.—Four stand gin complete. (Courtesy Continental Gin Co.)

spiked rollers, or agitators of some construction, which tear apart the large, somewhat dense bunches and throw the locks against wire screens which permit dirt to fall through.

*Distributor.*—From the cleaner the seed cotton is delivered to a large belt that travels over the top of all the gin stands (Fig. 99). Attached to this belt are fingers which assist in moving the cotton to the feeders above the stands. Each stand is regularly supplied with all the cotton it can handle. Any excess that the belt may have is dropped to the floor where the belt turns (see Fig. 99) and is known as the overflow. This cotton is taken up by the elevator nearby after all the cotton has been removed from the wagon.

In some gins a pneumatic distributor is used. This delivers the cotton to a cleaner separator above each gin.

*Feeder.*—Over each gin stand there is a device for supplying the gin saws below with cotton regularly and in small quantities. This is known as a feeder. The feeder commonly contains a spiked roller (Fig. 100), which picks up the cotton and so drops it that it will fall to the saws. In many cases the feeders have cleaning devices in connection, as shown in Fig. 100.

*Gin Breast.*—From the feeder the seed cotton falls directly into the gin breast, or roll box, as it is sometimes called (Fig. 101). Here the cotton comes in contact with the rapidly

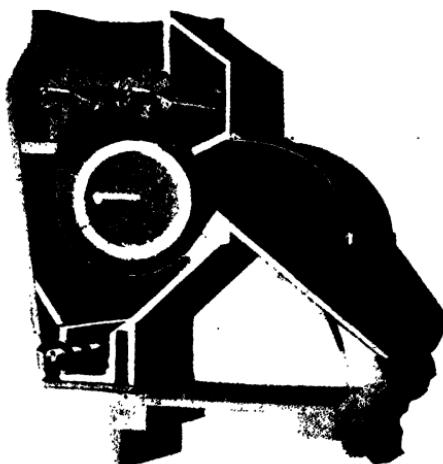


FIG. 100.—Combined feeder and cleaner. (*Courtesy Continental Gin Company.*)

revolving saws. When the saws strike the mass of seed cotton, they cause it to move, and soon form a cylindrical mass or roll which revolves rapidly. In this manner new bunches of cotton are brought against the saws almost continuously.

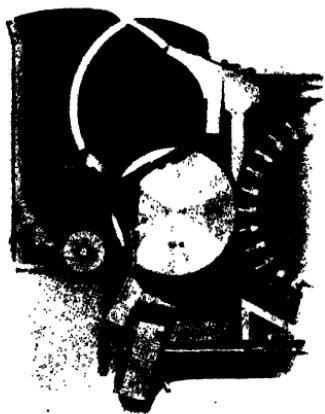
The front of the gin breast is movable. If it is so set as to lessen the size of the opening at the lower part of the breast, the seeds are held inside the breast longer and ginned closer.

Some gins are built with a double breast, into the outer compartment of which fall hulls, bolls, etc. These come in contact with the saws before they reach the regular roll of cotton. Gins of this construction are especially valuable for ginning bolly

cotton, or cotton that contains many burs, pieces of bolls, trash, etc.

**Saws.**—The gin saws are steel discs 10 or 12 inches in diameter (Fig. 101). The saw teeth on the circumference of the discs are somewhat hook-shaped, being made so as to give them maximum strength but so that they will cut the cotton fibers a minimum amount. For good ginning, the saw teeth must be kept sharp. Even under ideal conditions the teeth cut the fibers to some extent. The damage done is multiplied if the cotton is damp or if the saws are run too fast. Four hundred revolutions per minute is considered a proper speed for 10-inch saws; 12-inch

saws, on account of their greater circumference, need not run so fast to accomplish the same results. A single gin contains about seventy saws.



*(Courtesy of the Continental Gin Company.)*

the seeds to pass.

Some gins, like certain of the huller type which are designed for removing burs, broken bolls, etc., have two sets of ribs.

**Mote Board.**—The mote board is a movable board under the brushes of a gin. By moving this board an air space beneath the gin is enlarged or diminished. Proper adjustment of the mote board assists in removing particles of seed and foreign matter from the lint cotton.

**Gin Brushes.**—Just back of the gin saws is a revolving cylinder which bears numerous rows of bristles, or brushes, as they are called (Fig. 101). The brushes are set so as barely to touch the saws and are geared to run about three times as fast as the saws. By this means they remove the lint from the saw teeth, although they move in the same direction as the saws. The

brushes, when running, generate a current of air which not only assists in removing the lint from the saws but also in driving it toward the condenser near the press.

In some gins of recent manufacture an air blast, instead of brushes, is used to remove the lint from the saws (see Fig. 102). This method seems to be fully as satisfactory as the brush method.

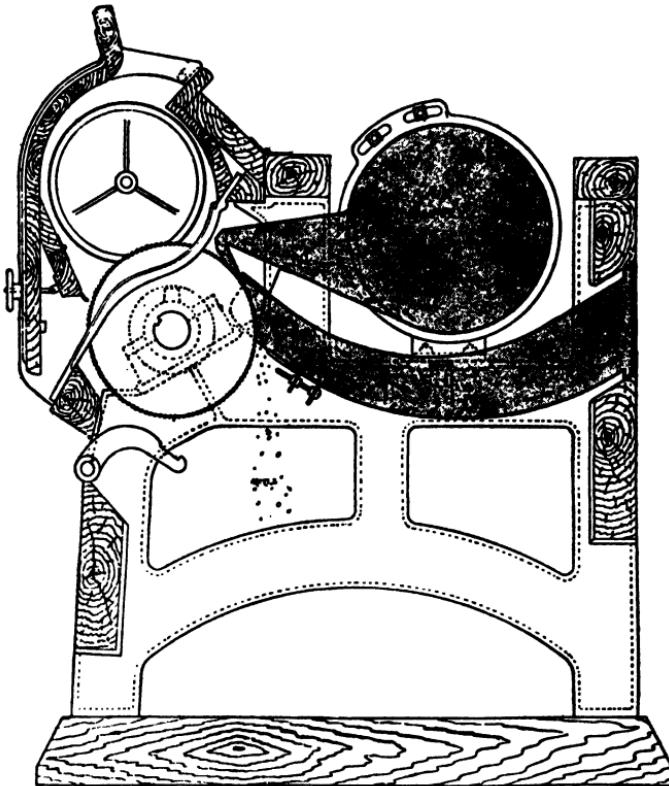


FIG. 102.—Air-blast method of removing lint cotton from gin saw. (After *Taylor*.)

*Condenser.*—The lint removed from the saws is carried by air blast to the condenser, which consists essentially of a large roller covered with wire screening, and a smaller wooden roller. The lint is blown against the screened roller, which allows the air to pass through but stops the lint, which collects on it. The rollers so turn as to press the accumulated lint between them, thus forming a fairly compact layer of cotton "bats."

*Press.*—From the condenser, the cotton drops into the press box, over the bottom of which has been spread bale bagging.

As the cotton collects in the box, it is packed every minute or so by mechanical trampers. After enough has accumulated to make a 500-pound bale, which amount is estimated by the pressman, heavy pressure is applied by hydraulic, screw, or other

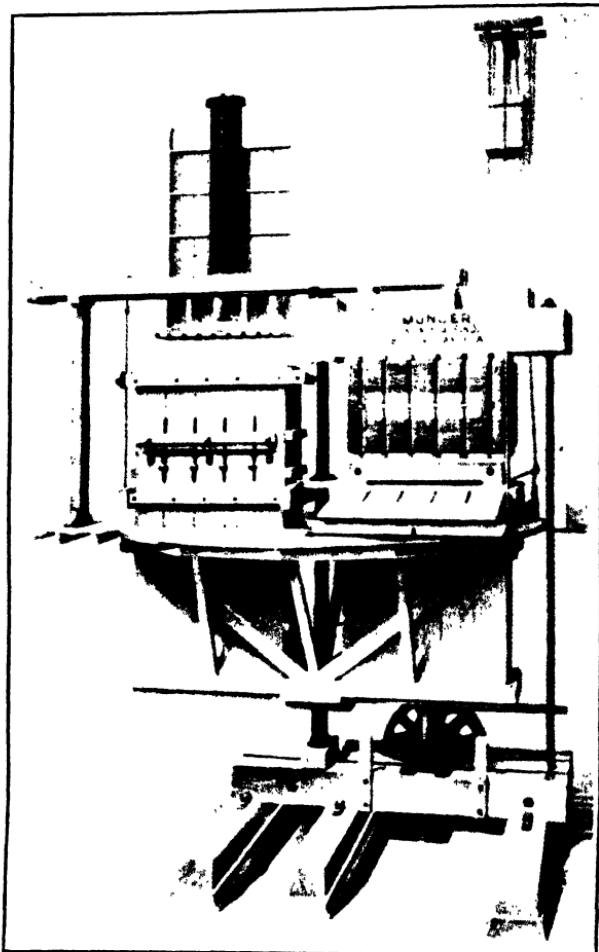


FIG. 103.—Revolving double-box press with 5-inch screw and plain steam cylinder trumper. (*Courtesy Continental Gin Company.*)

power. Just before the pressure is applied, a piece of bagging is placed over the upper part of the mass of cotton in the box. While the cotton is under pressure, the bagging is fitted over the sides of the bale (the bagging is usually not long enough to cover the sides completely), and six iron ties are put around it and

fastened. Pressure is now released. The cotton expands somewhat, but is held firmly in a compact bale by the bagging and ties. The bale is now complete. In most ginneries a double press box, like the one shown in Fig. 103, is used. This permits the gin to run continuously, since one box may be filling while the cotton in the other is being compressed and tied.

**Cotton Bales.**—Before lint cotton can be handled conveniently or marketed, it must be made more compact and tied in a package that can be handled satisfactorily. Various kinds of packages, or types of bales, have been made and are being made by different countries at present.

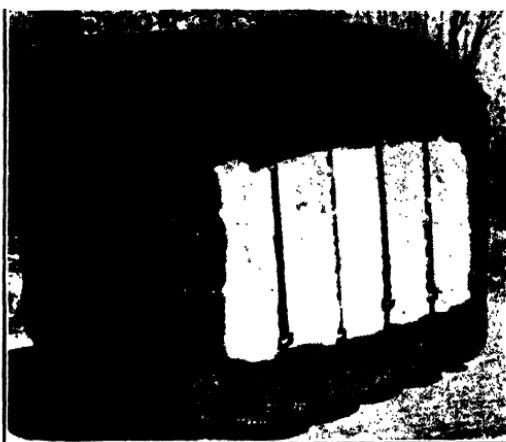


FIG. 104.—American flat bale.

In America, cotton was first packed in a large sack as a package for the market. This sack was commonly suspended beneath a hole in the gin-house floor, through which lint cotton was pushed. The cotton was packed in the sack by two men who tramped it. When the sack was packed as full as possible, the open end was sewed. These sacks weighed 200 to 300 pounds, and the cotton was compressed to a density of about 5 pounds per cubic foot.

These bags of cotton were bulky, requiring much space in ships. There was at once a demand for a package that would not take so much room in proportion to its weight. This demand brought into use the screw press, such as has been described in the preceding pages. The screw-press bales varied in weight considerably, but were intended to weigh 500 pounds. Their density was about 8 pounds per cubic foot.

About 1870, the metallic screw and hydraulic press came into use. By means of these the bale was given a density of about 12 pounds per cubic foot. The size of the press box was standardized to make a bale of uniform size—27 inches thick and 54 inches long. The width varied somewhat, depending on the compression of the bale, but was about 45 inches. The average weight was about 500 pounds. This bale was the same as the modern flat bale which is turned out by ginneries all over the South (Fig. 104).

*Round Bales.*—Different machines have been devised for making round bales, but such bales are not made extensively. The Bessonette bale, which is the type mostly used, is made by winding the bat around a central core. As the lint is wound, two rollers press against the roll, thus packing the fibers closely. Wound in this way, the fibers adhere. The result is a very compact cylinder of cotton which will not unwind nor expand. No ties are needed to keep it compressed. The finished bale is about 25 inches in diameter, weighs 250 pounds, and has a density about 33 pounds per cubic foot. After completion, the bale is covered with duck or hemp cloth, which is sewed on. A lint sample is taken while the bale is being made. The covering of the bale is not cut for sampling.

*Bales Made by Foreign Countries.*—The cotton bale made in India varies in size considerably, but the average weight is about 400 pounds. It is entirely covered with bagging and well bound with ties, which run around it spirally. It is a neat, well-protected package.

The Egyptian bale, when shipped, is said to be in better condition than the bale from any other country. It weighs from 700 to 800 pounds, and is compressed to a density of about 30 pounds to a cubic foot. It is completely covered with canvas and securely bound by numerous iron bands.

**Compress.**—With the increase in cotton production came further demand from railroads and ship lines for a more compact bale. This demand brought the bale compress into use. The compress is constructed much like a gin press, except that it is much stronger and can exert more pressure.

When a flat bale is put into a compress, the ties are removed and usually patches, pieces of bagging, are put over the holes in the old bagging and over the sides of the bale that had not been covered with bagging. A pressure of 120 pounds or more per square

inch is then applied. This reduces the bale to a thickness of just a few inches and a density of 50 pounds or more per cubic foot. The ties are then replaced, and usually two others, which are made by splicing pieces cut off the old ties, are added. When the pressure is removed the bale expands somewhat and becomes less dense, but the density remains above  $22\frac{1}{2}$  pounds per cubic foot. Bales are handled so rapidly at the compress that not much pains can be taken to give them a neat appearance; consequently, the compressed bales have irregular shapes and a ragged appearance (Fig. 105). Double the number of bales may

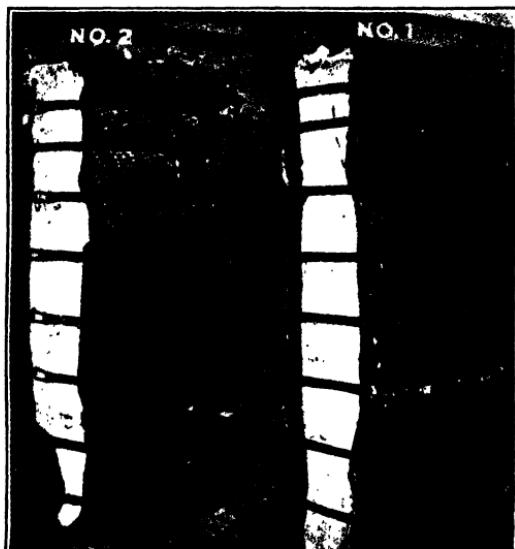


FIG. 105.—Compressed bales.

be placed in a car if they have been compressed. Compresses are to be found in the South in all towns of any size, and at all concentration points for cotton.

**Gin Compress.**—In order to avoid the expense of hauling bales to a compress and the extra labor of handling them there, a gin compress has been constructed. This is similar to the regular baling press at the gin, and is used instead of it, but it is built much stronger, so that more pressure may be applied to the bales. This system is surely more economical than the one in vogue, but it is not used extensively. Its adoption would call for new presses at the gins and the doing away with the compresses, in

which much capital is invested, and would require certain changes in marketing methods.

**Criticism of American Bales.**—The American cotton bale when it arrives in foreign markets is very ragged in appearance. The bagging has been cut at several places to draw samples; some of the cotton is exposed and dirty; and the whole bale has perhaps been damaged by exposure to the weather. The bad condition and appearance are due largely to our sampling and marketing systems. Almost every dealer that handles the bale feels that he must have a new sample from the bale, and

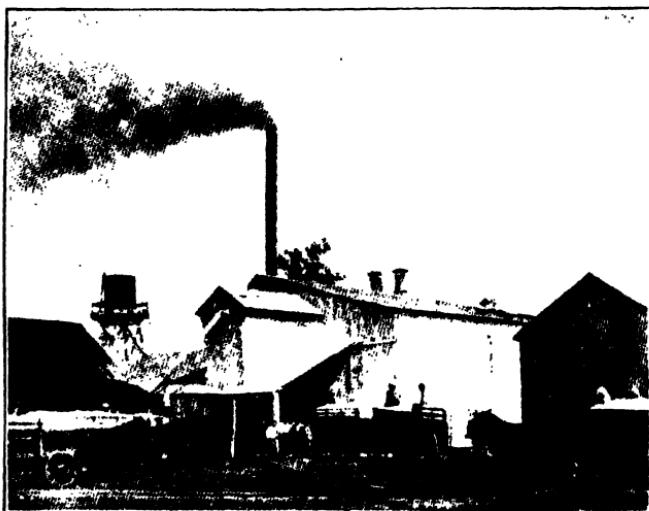


FIG. 106.—Plantation gin, showing loads of cotton waiting to be ginned.

usually he cuts the bagging at a new place to get the sample. The producer is far removed from the consumer. He feels that the consumer will never know where the bale came from, and that the price he receives for his cotton does not depend to any great extent, on how he handles the bale.

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## CHAPTER XVIII

### COTTON CLASSING

The staple of different kinds of cotton varies greatly in length, strength, and character. Different lots of cotton vary much in respect to color and amount of trash and foreign matter in them. There are other differences also that are very evident to persons engaged in the cotton trade, but not easily understood by people not well acquainted with the staple. Before cotton can be marketed satisfactorily, the different kinds must be named and designated in such a way that the seller may be able to explain just what kind of cotton he has to offer, and that the buyers may understand what is offered and be able to say what is the market value of cotton of such a quality. This need of a standardizing system for use in cotton marketing brought into existence the science, or art, of cotton classing. It is more of an art than a science, perhaps, because it is mastered more by practice than by study. While it is true that many cotton sales are made on the basis of samples or on type, there is nevertheless always use for terms in designating market quotations and various business transactions.

A few years ago, but very few persons except the cotton buyers in the larger markets knew anything about cotton classing, or grading and stapling cotton. The local buyers had a general notion of grades, knew clean, white cotton when they saw it, and in buying were careful to give themselves a good wide margin in price paid. They did not give the real market values of definite grades. The grower did not know what grade of cotton he had for sale; consequently, the price received depended more on the competition of buyers than on the merits of the cotton. In far too many instances the grower did not get the real worth of his cotton.

More recently much more interest has been taken in cotton classing. The subject is taught in most of the agricultural colleges in the South, in special cotton-classing schools, and in institute courses for farmers. County agents can secure sets of

Official Cotton Standards. Growers may then examine or study these, and by means of them get some notion of grades of cotton.

**History of Cotton Classing.**—Names for different grades of cotton were first used in Liverpool about 1800. Since that time there has been in use at all times some sort of a system of cotton classing, but, as a rule, it has been open to many objections. Until very recently not only did the markets in different countries have different standards, but even the standards varied in different cities in the same country. Liverpool used one system, New York another, and New Orleans still another. This made trading between the different markets inconvenient. As a rule, the same, or about the same, grade names were used in the different markets but they did not in all cases represent the same quality of cotton.

Grade names were used in America, to some extent, during the first half of the nineteenth century, but it was not until the latter half that a systematic effort was made to get the matter on a proper basis. At a meeting of representatives of the American Cotton Exchanges at Augusta, Ga., in 1874, the standards used by the New York Exchange were adopted for use in all the exchanges of the country. After the adoption of the standards, many of the exchanges made no systematic effort to preserve their samples; consequently, different standards were soon in use in different places, and much confusion resulted.

In 1909, because of complaints made by cotton growers, the United States government began working toward the standardization of cotton classing in this country. A committee consisting of expert cotton classers, prominent cotton growers, dealers, and manufacturers was appointed by the Secretary of Agriculture to confer with the government classers. After due deliberation and study of grade types from about thirty American cotton exchanges and types submitted by individual members of the committee, the committee made a unanimous report and submitted a set of nine standards for grade which it had prepared. Copies of these sets were prepared and temporarily placed in cotton exchanges, in colleges, and in offices of other organizations. Within 6 months after their promulgation, sets had been purchased by interested parties in twenty-one states, and also in England, Germany, and Mexico.

The use of the first standards prepared was not compulsory. They did not meet with universal favor because the trade considered them too high in grade, especially for the lower grades.

With the passage of the United States Cotton Futures Act in 1914 it became necessary to require the use of Official Government Standards. In order to have a set of official standards that would be thoroughly acceptable to the trade, some of the leading cotton classers of the country were called to Washington to work with the Department experts in the preparation of a new set of standards that would meet the objections raised against the old set. A set of new standards was thus prepared, and on Dec. 15, 1914, the Secretary of Agriculture gave notice that he had on that day established and did thereby promulgate standards for nine grades of white cotton designated as Middling Fair, Strict Good Middling, Good Middling, Strict Middling, Middling, Strict Low Middling, Low Middling, Strict Good Ordinary, and Good Ordinary, to be known as the Official Cotton Standards of the United States. The changes made in the standards made them acceptable to all interests in this country, and their use became general.

In 1915, the Secretary of Agriculture issued an announcement in which was defined certain kinds and conditions of cotton that were not tenderable on future contracts. Standards for color were established and promulgated in 1916; standards for American-Egyptian in 1918; standards for Sea Island in 1918; and standards for length of staple in 1918. In July, 1922, the Official Government Standards were again revised and certain changes made by a committee representing all branches of the cotton trade.

A numerical system was introduced in the revised standards to designate the different grades, No. 1 being assigned to Middling Fair, No. 2 to Strict Good Middling, and so on, higher numbers being given to the lower grades in numerical order. Additional designations for color were established. The complete list of grades and color designations now in use is shown in Table XXXV.

On Mar. 4, 1923, the United States Cotton Standards Act was passed by Congress. This act gave legal force to the Official Cotton Standards, established under the United States Cotton Futures Act, in all spot cotton transactions in interstate and foreign commerce. Their use was to be required after Aug. 1, 1923. This requirement made it very necessary that Liverpool and other foreign markets have the same set of standards as the United States. The desirability of this uniformity had been

TABLE XXXV.—GRADES AND COLORS OF THE UNIVERSAL STANDARDS FOR AMERICAN UPLAND COTTON

Blue-stained	Gray	Standards for grades of Upland cottons, white	Spotted	Yellow-tinged	Light-stained	Yellow-stained
3 B. 4 B. 5 B.	3 G. 4 G. 5 G.	1 or M. F.		2 T.		
		2 or S. G. M.		3 T.	3 L. S.	3 S.
		3 or G. M.	3 Sp.	4 T.	4 L. S.	4 S.
		4 or S. M.	4 Sp.			
		5 or M.	5 Sp.	5 T.	5 L. S.	5 S.
		6 or S. L. M.	6 Sp.	6 T.		
		7 or L. M.	7 Sp.	7 T.		
		8 or S. G. O.				
		9 or G. O.				

Symbols in regular type denote grades and colors for which practical forms of Official Cotton Standards are prepared. Symbols in italics represent the designations of cotton which in color is between practical forms.

The grades shown above the continuous black line are deliverable on future contracts made in accordance with Sec. 5 of United States Cotton Futures Act. Those below the line are untenderable on such contracts. (*After Palmer.*)

recognized by all the markets for some time, and several unsuccessful efforts had been made to bring about the use of uniform standards.

With the passage of the act mentioned above, the matter of universal standards was again taken up. In June, 1923, there was a conference in Washington of Officials of the U. S. Department of Agriculture and representatives of the Liverpool Cotton Association, the Manchester Cotton Association, the Syndicat du Commerce des Cotonns du Havre, and the English Federation of Master Cotton Spinners' Associations. The representatives from Liverpool held proxies from the associations at Bremen, Rotterdam, Ghent, Barcelona, and Milan. After discussion and the submission of recommendations by the visiting representatives, the official standards for grade and color for Upland cotton, with certain modifications, were adopted by all of the associations represented. The Liverpool representatives asked for certain changes in the white standards for Good Middling, Strict Middling, Middling, and Strict Low Middling, and it

was the wish of the foreign delegates that the name "Universal Standards" be used instead of "Official Cotton Standards of the United States."

A second conference was called during July, 1923, at which the associations mentioned above were represented, and in addition American merchants, exporters, spinners, and growers. This conference agreed on certain changes. The Secretary of Agriculture published an order putting into effect, on Aug. 1, 1924, the changes suggested by this last conference. Other standards not affected by the changes made in the conference were repromulgated, and the name "Universal Standards" was recognized as an alternative name.

**Cotton Standardization.**—A system of cotton classing or standardization must take into account many qualities of cotton and express in some way the degree in which any particular quality is manifested. These qualities cover such attributes as amount of trash, waste, or foreign matter in the cotton; the color of the fiber; length, strength, clinging, and bleaching qualities of the fiber; body of fibers; uniformity of fibers; damage to fibers in ginning; mixture of different kinds of cotton in a bale; etc. Each of these different qualities will be considered in some detail later.

**Classification According to Grade.**—The Universal Standards, which superseded the Official Cotton Standards of the United States, contain samples representing nine grades of white cotton, which are named Good Ordinary, Strict Good Ordinary, Low Middling, Strict Low Middling, Middling, Strict Middling, Good Middling, Strict Good Middling, and Middling Fair, the last-named grade being the highest. Each standard represents a full grade. The range of these grades is wide enough to include practically all white cotton, especially all that is harvested under ordinary conditions. Middling is the basic grade, or the grade on which market quotations are based. The relative value of grades above or below middling varies in different seasons, the value depending largely on supply and demand.

Other grade names are used for cotton that is tinged, stained, or discolored in some way. These will be discussed in a later paragraph.

**Factors That Determine Grade.**—The grade of cotton is determined by the amount of leaf fragments, trash, and foreign impurities in it; by its color, whether white, tinged, stained,

spotted, blue, or gray; and by the ginning, whether smooth and well ginned, or containing neps and gin-cut staple.

*Foreign Impurities.*—After a cotton boll opens, it dries out rapidly, and all of its parts, except the seeds, soon die. The bracts, the small leaf-like structures at the base of the boll, become very dry and brittle. When a boll is picked these bracts are apt to be broken more or less and small pieces carried away with the locks of cotton. This probably constitutes the chief foreign impurity found in lint cotton. During the early part of the picking season, it is about the only one. After frosts come, the large leaves of the plant are brittle and fragments of them become mixed with the cotton when it is picked. During the latter part of the season a considerable amount of cotton falls to the ground. If this is picked up, it is apt to carry with it leaf fragments, pieces of stems, trash of all kinds, sand, dirt, and dust. The addition of this cotton lowers the grade considerably, and is one of the main reasons why cotton from late pickings is of low grade. Leaf fragments of pinhead size, if numerous, are considered more objectionable than larger ones, because they are harder to remove from the cotton in manufacturing processes.

Cotton exposed in the open boll collects a certain amount of dust and sand blown about by the wind. Bolls near the ground collect a considerable quantity of sand and dirt splashed on them by beating rains. Locks picked up from the ground carry still more. When in excessive quantities, the sand and dirt contained may be considered apart from the grade, and cause the cotton to be penalized in consequence.

There are always some small, undeveloped seed in the seed cotton. A part of these pass between the gin ribs with the lint and constitute an impurity known as motes. Certain years when the weather is very dry, or when the cotton plants are defoliated by insects or otherwise, these immature seeds may be rather abundant. The little stem at the small end of the seed may be broken off in ginning, or if the roll is too tight and saws run fast, there may be fragments of hulls from cut seeds in the lint. All of these impurities, of course, lower the grade of cotton.

In parts of the Cotton Belt there is considerable snapped or bolly cotton. The cotton is not picked in the usual way, but unopened bolls, open bolls, burs, and all are gathered. This cotton is ginned on a gin that will tear the bolls open and take

out the lint cotton. While this cotton is of value, a large portion of it is low in grade because of the presence of much trash, boll fragments, etc.

The classification of cotton may be raised one or two grades by ginning it on one of the improved gins now in use which have special cleaner devices.

*Color.*—Although there is a separate set of standards for colored cotton or cotton that is "off" in color, the characteristic of color has a bearing on grading and is considered in the classing of regular grades of cotton. According to the Universal Standards, to grade Good Middling or above, a sample must be a bright, creamy, or white color and be free from any discoloration. Below this grade some latitude is allowed in range of color. The cotton may be creamy, white, or "dead" white. In the lower grades, grayish, dingy, or slightly reddish colors are allowable.

*Ginning.*—The quality of the ginning also has a bearing on the grade of a sample of cotton, but it is not of primary consideration. If the ginning is very bad, the cotton may be considered as irregular, and penalized accordingly. Bad ginning adversely affects the grading in that it makes cotton look stringy, rough, and tangled.

If cotton is fed to the gin breast too rapidly, or if the saws are run too fast, or if the cotton is damp when it is ginned, the lint is apt to be gin-cut or show neps. Gin-cut cotton has a "chewed-up" and "stringy" appearance. Neps are small masses of densely matted and tangled fibers. They appear as small white masses. When neps are present in quantity, they are hard to remove, and show in the finished yarn if they have not been removed.

If the seed cotton is stored a few weeks before ginning, it dries out thoroughly. It then gins better, and there is probably less gin cutting of fibers. As has been mentioned in Chap. VII, some authorities are of the opinion that the luster of cotton is improved by storage before ginning, but this has not been demonstrated conclusively.

*Description of Grades.*—The different grades typified by the Universal Standards are different, but the difference is mainly in the degree in which the various qualities appear. Consequently, it is impossible to draw sharp lines separating them or to give delimiting descriptions. Samples of cotton must be seen and studied to get a definite conception of the grades.

*Good Ordinary*.—A sample of Good Ordinary cotton contains a considerable quantity of leaf particles, and it may have also a sprinkling of motes, seed fragments, and occasional gin cuts. It may contain 1 per cent or less of sand, dust, or dirt. This grade is considered white cotton, but it has some tinge or stain and is usually more or less smoky and discolored.

*Strict Good Ordinary*.—Strict Good Ordinary differs from the preceding grade chiefly in having a lesser amount of the imperfections named.

*Low Middling*.—Low Middling appears to be considerably whiter than the first grade mentioned, but there are indications of tinge and stains in spots. There is also a considerable quantity of leaf and motes, and perhaps some gin cuts and neps.

*Strict Low Middling*.—Strict Low Middling is intermediate between Middling and Low Middling in characteristics.

*Middling*.—Middling cotton is white and nearly free from gin cuts and neps, but it contains some pieces of cotton seed, and a medium amount of fairly large pieces of leaf. Middling cotton may have the color of the higher grades, but the leaf particles and other impurities it contains hold it to its grade. Middling is the basic grade both in respect to market price and to the measuring of other grades. Different samples of middling cotton may vary in a way. One sample may rank high in respect to color, but low in respect to quantity of leaf and motes. Another sample may be from cotton that was so carefully picked that it contains but little trash, but it is held down by having too much color or discoloration for the higher grades. Within certain limits the grade is determined by the average of the qualities of the sample. Of course, a sample that is badly off in respect to color, gin cutting, or some other characteristic could not be classed as Middling cotton even if it had excellent other qualities.

*Strict Middling*.—The Strict Middling grade is, of course, one grade better than Middling, but it is difficult to say just wherein it is better. In general, it is a slightly better-looking cotton, and has better color and less leaf and trash. This grade is very popular with the American spinner of staple cotton.

*Good Middling*.—Good Middling cotton has a good creamy-white or white color, is free from neps and gin cuts, and contains only a few foreign particles and but little leaf trash. Cotton that is picked early in the season before it has been rained on should grade Good Middling or possibly better if it is well

ginned and the picker was careful. Very little of the commercial crop grades higher than Good Middling unless special effort is made in picking.

*Strict Good Middling.*—Strict Good Middling cotton has a bright creamy or white color, has no neps or gin cuts or broken seeds, and has fewer pieces of leaf than is to be found in Good Middling.

*Middling Fair.*—Middling fair is the highest grade represented in the Universal Standards and it is rare in commercial trade. The cotton is of a bright creamy or white color, fluffy, and well ginned. About the only imperfections to be found are a very few leaf fragments.

**Grades above and below the Official Government Grades.**—The two grades, Strict Middling Fair and Fair, have been mentioned for cotton of a higher grade than Middling Fair, the highest grade represented in the Government Standards. These grades are more theoretical than real, since such cotton never appears on the market and is rarely seen. These grades are not now recognized.

Three or four different grades for cotton of lower grade than Good Ordinary have been listed. These are, in order of rank from highest to lowest, Strict Ordinary, Ordinary, Low Ordinary, and Inferior. These grades are not used much by the trade. There is a considerable quantity of this very low-grade cotton, but it is largely called "dogs," or "dog tail," and is sold on basis of sample or type.

**Half and Quarter Grades.**—Prior to the issuance of the Government Standards, Middling Fair, Good Middling, Middling, Low Middling, and Good Ordinary were considered as full grades, while the grades between these, or the grades designated with the prefix "Strict," were regarded as half grades. All these grades were made full grades by the Cotton Futures Act of 1914. Since that time the term "half grade" has largely passed out of use in this country.

When grading cotton, the classer frequently handles samples that are a little too good for a certain grade but hardly good enough for the next higher. These, being between the half grades formerly in use and whole grades, have been termed quarter grades and designated by the names "fully" or "barely." "Fully," when used before the name of a certain grade, indicated a quarter above, while "barely" when used in this way

indicated a quarter grade below the regular grade. The terms "full style" and "shy" express about the same as "fully" and "barely" respectively. Although these quarter-grade designations are not sanctioned in the present standard classification, they are used more or less commercially.

According to Palmer,<sup>4</sup> it is the present custom of the government classers to give cotton of intermediate grade the classing of the lower grade unless there is some special reason for classing it otherwise.



FIG. 107.—Government classers preparing boxes of cotton samples which illustrate the official standards. (*Courtesy G. L. Meloy.*)

**Boxes of Official Standards.**—The expert cotton classers of the U. S. Department of Agriculture have prepared boxes of cotton samples illustrating the nine official grades of white Upland cotton (Fig. 107). Each large box contains twelve fair-sized samples of cotton chosen to illustrate the variation allowable within one grade (Fig. 108). The samples are sewed in the box so that they cannot be removed or tampered with, and a full-size photograph showing the appearance of the samples when issued is pasted on the inside of the lid of each box. By a comparison of the samples with this picture, the disturbance

of leaf particles, etc., may be detected. The box has a hinged lid which, when closed, will keep out dust and light.

These standards are very useful in giving a beginner in the art of cotton classing a notion of the different grades, and they help keep experienced classers from changing their ideas. Sets are sold by the government for a moderate sum and are in use in agricultural colleges, cotton-classing schools, cotton exchanges, and in the sample room of many cotton buyers.

To show their color satisfactorily, the standards should be placed in a room well lighted by skylights. If this is not avail-

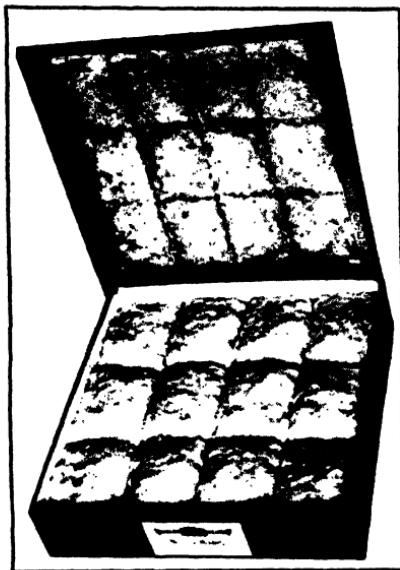


FIG. 108.—Box containing twelve cotton samples which show the range within one grade of the official standards.

able, a room lighted by windows on the north side of the room is next best. Direct sunlight should never be allowed to fall on the samples. The true color cannot be judged in sunlight, and the sun bleaches out color.

In using the standards for comparison, the classer rolls the sample he is examining into a shape resembling that of the standard samples and then holds his sample against the side of the standard boxes until he finds one that matches his. If the boxes are tilted at an angle of about 45 degrees, the samples may be inspected more easily, and there is less likelihood that the student

**Classification on Basis of Color.**—The amount of discolored cotton harvested varies considerably in different years, depending largely on the time killing frosts occur. If they are early, the quantity is large. Earle and Taylor<sup>1</sup> have estimated that, on the average, one fifth of the crop cannot be classed as white cotton. Since the advent of the boll weevil, the average percentage is higher. During some years the percentage of discolored cotton runs as high as 35 or more. From this it may be seen that the discolored cottons are of considerable importance.

The discolored cottons have, of course, been handled by the cotton trade for years, but no distinct classes were established for all of the different kinds. They were classed as white cottons, but designated as "off color," "spotted," "tinged," or "stained," etc. The recent official classification of the U. S. Department of Agriculture recognizes seven groups of Upland cotton on basis of color. These are, as shown in Table XXXV, White, Blue-stained, Gray, Spotted, Yellow-tinged, Light-stained, and Yellow-stained. Minor color variations occur in each of these divisions. These variations are probably more marked in the white cotton than in any other. This division, as was brought out in preceding paragraphs, contains cotton that is not altogether white but is more or less tinged with different colors.

Blue-stained cotton has a more or less pale-blue or pale slaty-white color, which has been caused by a mildew or exposure to the weather, either before picking or in the bale. Blue-stained cotton will not bleach well, and cannot be dyed satisfactorily except with heavy dyes. Blue cotton is apt to be weak. The gray cotton is intermediate between blue and white. Spotted cotton is lighter than tinged cotton, but has too much yellow color in parts to be called white cotton. Yellow-tinged cotton has a light yellowish or faint reddish color throughout. Such cotton bleaches and dyes well and consequently is of consider-

able value. Yellow-stained cotton is similar to yellow-tinged, except it is darker in color. The difference is largely in degree of color. Frost on unopened bolls is the principal cause of the yellow discoloration.

The discolored cottons are considered inferior to white in value. As may be seen from Table XXXV, a large part of the grades of these cottons are not tenderable on future contracts.

*Grades of Discolored Cotton.*—The discolored cottons are first classed according to color, as "Blue-stained," "Yellow-tinged," etc. Next they are examined with reference to presence of foreign matter and to ginning preparations. On basis of their appearance in respect to these qualities, each is given a specific grade classing, as, for instance, Good Middling, or Middling. None of the discolored cottons are graded higher than Strict Good Middling, and most of them not any higher than Good Middling. None are graded lower than Low Middling. The complete range of grades is shown in Table XXXV.

*Grades of Sea Island Cotton.*—Sea Island cotton is considerably different from Upland cotton and so requires a different system of grading. It has a very long, fine, silky staple, and is ginned on roller gins, which give the lint cotton a tufted or wadded appearance very different from lint from saw gins. Crushed seeds are also more common than in the lint from saw gins. The lint of Sea Island resembles that of Upland in color, but is somewhat more creamy.

Official standards for grade for Sea Island cotton were established in October, 1918. These were based on the commercial grades of Sea Island cotton in use at that time, and are designated numerically in order from highest to lowest as Nos. 1, 2, 3, 4, 5, and 6. Half grades, intermediate between these grades, are recognized and designated by the fraction  $\frac{1}{2}$ , as Nos.  $3\frac{1}{2}$ ,  $4\frac{1}{2}$ , etc. The one set of grades covers, or takes cognizance of, color, foreign impurities, and ginning qualities. Boxes of samples illustrating the different grades of Sea Island cotton were prepared by government classers, and were available by purchase from the Department of Agriculture for a time, but they have been discontinued due to the scarcity of Sea Island cotton.

*Grades of American-Egyptian Cotton.*—American-Egyptian cotton is different from Upland cotton and also somewhat different from Sea Island. It is ginned on roller gins, and as the

seeds are somewhat more fuzzy than the seeds of Sea Island, it is, according to Palmer,<sup>4</sup> harder to gin, and gives a more crinkled or crimped sample of lint, which contains more crushed seeds and is darker in color. The highest grades of American-Egyptian cotton are of a creamy color, while the lower tend to be darker. American-Egyptian is derived from cotton grown in Egypt, some varieties of which are brown in color.

Official Standards for American-Egyptian cotton were established by the government in 1918. The grades recognized are designated by the numbers 1 to 5 inclusive, the lowest number being the best grade. Half grades, as in Sea Island cotton, are designated by the fraction  $\frac{1}{2}$ . Boxes of samples illustrating the different grades of American-Egyptian cotton have been prepared by the U. S. Department of Agriculture.

**Classification According to Length of Staple.**—If the premium paid for the extra length of long-staple cotton is considered, the classification for length of staple appears to be a matter of considerable importance. Less than 20 per cent of the cotton produced in the United States, however, is long-staple cotton on which premium is paid. A large part of the cotton grown is sold in primary markets without regard to its staple length.

Cotton with a staple of  $1\frac{1}{16}$  inches in length or less is generally considered short-staple cotton, or short cotton, but is sometimes referred to as medium-staple if the length is 1 or  $1\frac{1}{16}$  inches. Staple  $1\frac{1}{8}$  inches in length or longer is called long-staple cotton, or staple cotton. Cotton  $1\frac{1}{8}$  to  $1\frac{3}{16}$  inches is sometimes called "Binders," and cotton with a staple length more than  $1\frac{1}{4}$  inches is called extra-staple cotton. At present there is a tendency to restrict the term "short cotton" to cotton less than an inch in length. Most of these terms are used without close discrimination.

**Official Standards for Length of Staple.**—Official standards of the United States for length of staple were established in October, 1918, for the following staple lengths expressed in inches or fractions of an inch: below  $\frac{3}{4}$ ,  $\frac{3}{4}$ ,  $1\frac{3}{16}$ ,  $\frac{7}{8}$ ,  $1\frac{5}{16}$ , 1,  $1\frac{1}{32}$ ,  $1\frac{1}{16}$ ,  $1\frac{3}{32}$ ,  $1\frac{1}{8}$ ,  $1\frac{5}{32}$ ,  $1\frac{3}{16}$ ,  $1\frac{7}{32}$ ,  $1\frac{1}{4}$ ,  $1\frac{9}{32}$ ,  $1\frac{5}{16}$ , and so on with gradations of  $\frac{1}{32}$  inch. A difference in staple length less than  $\frac{1}{32}$  inch is hardly measurable in practical cotton classing or stapling. In practice, the fractional part  $\frac{1}{32}$  is rarely used. Lengths are expressed with the fractional units none of which are smaller than  $\frac{1}{16}$  inch, as  $1\frac{1}{16}$ ,  $1\frac{1}{8}$ ,  $1\frac{1}{4}$ , etc. In case the length

cannot be measured in even sixteenths, it is the custom to add the suffix "full" to the nearest sixteenth. This is equivalent to adding  $\frac{1}{32}$ , since  $1\frac{3}{16}$  full means  $1\frac{7}{32}$ . This intermediate length is also expressed by giving both the even numbers nearest and connecting them with "to"; for example,  $1\frac{7}{32}$  may be expressed as "1 $\frac{3}{16}$  to 1 $\frac{1}{4}$ ." The intermediate length  $1\frac{7}{32}$



FIG. 109.—A photographic representation of the official cotton standards of the United States of those lengths of staple for which types are available for distribution, each respective length as shown being obtained from the original type bale. (Courtesy G. L. Meloy.)

may also be indicated by the expression "not less than 1 $\frac{3}{16}$  inches or over 1 $\frac{1}{4}$  inches."

Actual samples showing the following staple lengths have been prepared by the U. S. Department of Agriculture and are on sale:

For Upland Cotton, 3 $\frac{1}{4}$ , 7 $\frac{1}{8}$ , 1 $\frac{15}{16}$ , 1, 1 $\frac{1}{32}$ , 1 $\frac{1}{16}$ , 1 $\frac{3}{32}$ , 1 $\frac{1}{8}$ , 1 $\frac{5}{32}$ , 1 $\frac{3}{16}$ , 1 $\frac{7}{32}$ , 1 $\frac{1}{4}$ , 1 $\frac{9}{32}$ , 1 $\frac{5}{16}$ , 1 $\frac{11}{32}$ , 1 $\frac{3}{8}$ , and 1 $\frac{1}{2}$  inches (Fig. 109).

For American-Egyptian cotton,  $1\frac{1}{2}$ ,  $1\frac{5}{8}$ ,  $1\frac{3}{4}$  inches.

These samples show actual length of fibers without reference to character or grade. For exact measurements the temperature must be 70°F. and the relative humidity of the air 65 per cent.

The length of the staple is sometimes expressed in millimeters. This is especially true in European countries.

**Determining Staple Length.**—Much practice and skill are required to determine the length of cotton fibers, or, in other words, to "staple" cotton. The fibers vary in length, their length varies with the moisture of the air, and they are much tangled, bent, and twisted in the cotton sample. Some care must be taken in drawing out the fibers to be measured in order to have a representative sample, and after they are drawn and arranged parallel, there may be a question as to the exact length of the "pull," since some fibers are slightly longer than others. In fact, within narrow limits, scarcely any two fibers are exactly of the same length. In measuring the stapler must use his judgment in striking an average.

An experienced classer is so adept at stapling cotton that he can judge the length of the staple in a measure simply by grasping a sample and pulling it apart. For more accurate work, he "pulls" the staple after a plan similar to the following one outlined by the specialists in the U. S. Department of Agriculture.

**Detailed Description of Method of Pulling Staple.**—Grasp in the two hands a tuft of cotton of a size convenient for the purpose (about  $\frac{1}{4}$  ounce). Hold it firmly between the thumb and forefinger of each hand, with the thumbs placed together, the fingers turned in toward the palms of the hands, and the middle joints of the second, third, and fourth fingers of each hand touching the corresponding joints of the fingers of the other hand, so as to give a good leverage for breaking the cotton.

Pull the cotton slowly apart with about the same leverage of each hand on the joints of the fingers, separating the tuft of cotton into two parts.

Discard the part remaining in the right hand.

Grasp with the thumb and forefinger of the right hand the end of the tuft of the cotton retained in the left. The point of pressure on the cotton in the left hand is just below the joint of the thumb and at the nail joint of the forefinger.

With the right hand draw a layer of fibers from the cotton held in the left hand.

Retain in the right hand the layer so drawn.

Repeat this operation four or five times, placing each successive layer directly over the fibers previously drawn. Be careful that the ends of all the layers are even with one another between the thumb and forefinger of the right hand.

After discarding the cotton in the left hand, hold the fibers thus obtained between the thumb and forefinger of the right hand and smooth them with the thumb and forefinger of the left hand.

Place these fibers on a flat horizontal surface with a black background.

Block off the ends of the fibers with a cotton-stapling rule, so as to indicate the length of the bulk, or body, of the fibers.

Then measure the distance between the blocked-off ends.

If preferred, the left hand may be substituted for the right and the right for the left, as the case may be, throughout the process here described.

**Classification According to Character of Staple.**—Character of staple is a matter of much importance to spinners and manufacturers of cotton goods, yet it is not at all understood by cotton growers and but vaguely grasped by many cotton buyers. Character has to do with the strength, body, uniformity, drag, elasticity, and other qualities of cotton fibers. Most of these attributes are rather intangible and hard to measure. There are no standards with which to make comparison. The classer is guided by his training and experience, as he interprets the "break" and "drag" of the fibers when he pulls them apart, and when he interprets the "feel" of the fibers.

**Strength.**—The strength of cotton fibers, or yarns, may be determined fairly accurately by means of a fiber-testing machine, such as was described in Chap. VII. The strength of fibers may be determined roughly by a cotton classer by breaking a small tuft when the ends are clasped firmly between the thumb and forefinger of both hands.

Strength is a desirable quality in cotton fibers, since the strength of yarns and the quality of the goods made from the yarns depend in large measure on the strength of the fibers.

**Body.**—By body of cotton is meant the relative solidity or density of a mass of the fibers. The fibers appear to fit or cling together closely and to make a firm sample. Good soil usually produces better-bodied cotton than poor soil. The cotton from poor soil tends to be light and fluffy, which are not qualities of

The uniformity of fiber can be judged to best advantage by combing out the lint of different plants in the field. Uniformity in sample of ginned cotton can be judged to best advantage by making a large number of "pulls" from a single sample.

*Drag*.—Drag is a term used to indicate the resistance offered by fibers in being pulled apart, or drawn past one another. Good drag is considered a desirable spinning quality, because fibers with good drag cling together well in spinning.

*Silkiness or Fineness*.—Silkiness, or fineness, is a desirable quality in cotton that is to be used in making fine fabrics. Such cotton feels very soft and smooth. As a rule, the fibers are long and of small diameter.

**Drawing Sample from the Bale**.—Where gin compresses are in use or in gins where round bales are made, lint samples are taken while the bale is in the press; therefore it is not necessary to cut the bagging to draw them. Most flat bales are cut and sampled one to several times. Frequently, each successive buyer wants a new sample.

There is no special art in sampling cotton, but the operator should know how to do it and understand the importance of correct procedure. The sample should be representative of the entire bale, and to insure this it is necessary to cut each side of the bale.

Miller<sup>2</sup> gives the following instruction for sampling a bale of cotton:

The cut should be semicircular in form, made with a sharp knife and deep enough to cut through at least an inch of cotton in depth. With the fingers digging into the opposite end of the cut from the sampler, he should gradually work them under the cotton as he draws his hands toward himself, at the same time tearing it up until he has a sufficiently large sample loosened on one side of the cut. Beginning again in the

cut at the opposite side from himself, he should draw the sample as he brings his hands forward. The cotton drawn should be a sample of about the same thickness all the way across the cut. Keep the sample intact; that is, do not draw small quantities repeatedly and attempt to make a sample by combining them.

Hooks, instead of the fingers, may be used in pulling out the sample. Drawn samples that are to be preserved should be rolled and wrapped securely with heavy wrapping paper. A numbered tag is fastened to the bale, and a card bearing the same number is enclosed in the sample.

**Classing Samples.**—As was shown previously, it is necessary to have proper light to judge the color of cotton satisfactorily. Rough classification may be made in the open air, but for careful work the samples are carried to a cotton sample room, where the right kind of light may be had (Figs. 107 and 111). With his back to the light, the classer holds up the sample, noting color, foreign matter, etc. The sample is then opened between successive layers and a mental average taken of the appearance of the whole sample. The grade given the sample is on the basis of this average. In case the sample shows that the two sides of the bale are different, the grading is based on the appearance of the poorer half.

**Licensed Classifiers.**—Under Sec. 3 of the United States Cotton Standards Act approved March 4, 1923, it is provided that the Secretary of Agriculture may, upon presentation of satisfactory evidence of competency, issue to any person a license to grade or otherwise classify cotton and to certificate the grade or other class thereof in accordance with the Official Cotton Standards of the United States.

Application for license to classify cotton is made to the chief of the Bureau of Agricultural Economics. Upon presenting satisfactory evidence of his competency, the payment of a license fee of \$10, and agreeing to comply with the terms and regulations of the Cotton Standards Act, the applicant may be given an official license to classify cotton for a period of one year. This license may be renewed subsequent years at a cost of \$5 annually.

For the classification and certification of any cotton or samples, a licensed classer may charge fees as follows:

1. If the classification is with respect to grade only, at the rate of 15 cents a bale.

2. If the classification is with respect to staple only, at the rate of 15 cents a bale.
3. If the classification is with respect to any other single quality, at the rate of 15 cents a bale.
4. If the classification is with respect to two or more of the qualities specified in paragraphs 1, 2, or 3, at the rate of 30 cents a bale.

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## CHAPTER XIX

### COTTON MARKETING

As is well known, millions of bales of cotton are produced every year. Nearly all of this cotton is hauled to the market and sold. The consumers live all over the world, a large number in regions far removed from the fields where the cotton is grown. Much of the product is spun and woven into cloth in mills thousands of miles from the cotton fields. An army of men are required to buy this cotton and distribute it to the manufacturers that need it for making cloth or for other purposes, and millions, even billions, of dollars are required to finance the operations incident to this great volume of business. It should be the object of marketing to convey the commodity from the producer to the consumer by the shortest route and at the least possible cost, so that the producer may receive a satisfactory price for his cotton and the consumer get the goods he buys at a reasonable figure. From data which will be given later in this chapter it appears that the difference between the price the consumer of cotton goods pays and the price the producer of the raw cotton gets is too great, being in a ratio of about 5 to 1. More than 75 per cent of the increase comes after the cotton has reached the large concentration points, like New Orleans.

**Brief History of the Cotton Trade.**—Prior to and during the eighteenth century the manufacture of cotton goods in England was carried on by spinners and weavers in their homes. The goods made were of the rougher sort. The raw cotton was obtained principally from the West Indies. The system of marketing was very simple, the weaver being buyer, manufacturer, and seller. When the cloth was made, he carried it to the town market to find purchasers. As the quantity of goods manufactured increased, there was need for middlemen or merchants to deliver material to the spinners and weavers and in return receive cloth for sale in the market. About 1760 small factories sprang up. Since the quantity of raw material consumed by these was considerable, it came to be the business of

certain men to buy and furnish the manufacturers with raw material. Thus special cotton merchants or factors came into existence. London and Liverpool were the chief import centers for cotton coming from the West Indies. Importers sold cotton to factors, who, in turn, sold it to the manufacturers.

Some cotton was grown in most of the southern English colonies in North America from early times, but it was not until near the close of the eighteenth century that export trade began. There is record of eight bags of cotton being shipped to England in 1784. At first the English spinners were prejudiced against American cotton. They had not tried it and imagined that it was inferior, but a trial soon convinced them that it was even superior to cotton from India. In 1791, America exported 189,500 pounds of cotton to England. France soon began to want American cotton. In 1801, she imported 844,728 pounds, and by 1806 the amount was increased to 7,082,118 pounds.

In 1787, the first cotton mill in America was erected in Massachusetts. This gave an impetus to home demand for raw material. The War of 1812 stopped the cotton trade with England and for a time depressed the industry. After the war, trade was revived, the demand became good, and cotton commanded a fair price. The saw gin and slave labor made the production of a quantity of lint cotton an easy matter. Transportation was poor, however. The cotton had to be hauled in wagons to river landings or export ports for transportation.

Prior to the Civil War in America, most of the American cotton was sold through commission men, who were situated in the export cities of the South and who were, in most instances, the only intermediaries between the producers and the importers in European countries. The commission men handled cotton just as any other article of commerce. Market conditions were not satisfactory because of lack of ready means of communication and a central point from which quotations might be derived. There were no cotton exchanges, and hence no future markets.

At the beginning of the Civil War, America was producing more than half of the world's supply of cotton. At the close of the war, practically none was being produced. Prices advanced to extreme figures; some Middling cotton is reported to have sold for \$1.89 per pound, and the average price was probably about \$1 a pound. No regular shipments to New York were made during the latter part of the war. The only cotton received

was some that was captured by the federal government through its blockade of southern ports or that was confiscated in the South. These lots of cotton were, in some instances, bought by speculators, and considerable profit was made. This led to much speculation. Speculators were so anxious for cotton that they began to buy "cotton to arrive." This was probably one of the steps which led to the development of the cotton exchanges where "futures" are bought and sold.

In 1866, the Atlantic cable was laid. This brought the American and European markets into close contact, and stimulated trade. Soon after the Liverpool and New York Cotton Exchanges were established, and the cotton trade began to follow a system similar to the present one. The commission men who previously had received cotton at every port were displaced by local cotton buyers, who established themselves in all towns where cotton was ginned or assembled in any quantity. There is some advantage to the grower in the new plan. The local cotton buyer examines individual bales, and is more inclined to pay the grower just what each is worth than the former commission merchant, who figured on a rather wide margin.

The distribution of American cotton to various countries of the world is shown by the following table, which is taken from a table prepared by the Liverpool Cotton Association.

TABLE XXXVI.—DISTRIBUTION OF AMERICAN COTTON

Years	Per cent exported to					Per cent taken by American spinners, North and South
	Great Britain	France	North Europe	Other ports	Total	
1851-1856	52.70	13.13	5.86	5.91	77.60	22.40
1870-1875	49.30	6.79	10.22	2.94	69.25	30.75
1890-1895	37.28	7.59	16.06	6.02	66.95	33.05
1910-1915	25.45	6.72	18.22	9.98	60.37	39.63
1920-1923	13.50	5.58	13.51	13.27	45.86	54.14

The foregoing table shows that during the last 70 years the relative amount of American cotton taken by Great Britain has gradually declined, while the relative amount taken by American spinners has increased greatly. Great Britain is taking about one-half as many bales as she was taking 50 years ago, whereas the American mills are using several times as many.

Several of the cotton-producing countries of the world are competitors for the European trade. India and Egypt are the leading rivals of the United States. India produces a great deal of cotton, but the quality is mostly rather poor, and considerable is used for home consumption. Egypt produces more than a million bales of cotton annually. This is of excellent quality and most of it is exported. The production of cotton in Egypt is at present limited by the lack of more land suitable for cotton growing.

**Present System of Marketing.**—As has been said in previous paragraphs, the machinery of cotton marketing in use today is extensive and complex. There are three large cotton exchanges on which contracts for "futures" or future delivery of cotton are bought and sold. These exchanges keep in closest possible touch with the growth and market conditions of cotton in all parts of the world. The trading in the exchange market is influenced by the data gathered. Results of the trading taking place are telegraphed to all parts of the world, and become the basis of market quotations everywhere. Prices prevailing in "spot" markets, that is, markets to which a large volume of cotton is shipped for sale, are governed very largely by the quotations from the exchanges which deal in future contracts, or "futures," as they are commonly called.

There are primary markets at nearly every cross-road hamlet in the South, larger interior markets in the larger towns and cities, consuming markets in cities where there are cotton mills or near to them, and export markets along the seacoast and on the Mississippi River. There are numerous buyers, brokers, commission men, and cotton dealers of various kinds. Warehouses are numerous, large, and mostly well constructed and well managed. Most of these units of the marketing system will be discussed in the following pages.

**Primary Markets.**—In nearly every small town there is at least one cotton buyer. In most instances this is the country merchant. Census Bureau figures of 1920 show the average size of improved farms in the South to be 47.3 acres, including only land under cultivation. From this it may be seen that the average size of the farm is small. Most of the cotton produced is grown by small farmers, many of whom have to have some financial assistance in making their crop. This assistance is

commonly given by either the country merchants, the local banks or cotton factors.

Formerly, many cotton factors in the larger towns entered into business relations with farmers and loaned them money to use in "making a crop." They, of course, charged a good rate of interest on the money loaned, and made a profit on the cotton after it was sold to them. In many instances the factors operated with but very little capital of their own. They secured money from banks or other sources by means of the paper that the farmers had given them, and did not pay the growers for their cotton which was consigned to them until after it was sold. More stringent financial regulations now in force have interfered with their system of carrying on business, and as a consequence they are passing. To be sure, there are factors who are financially strong and are doing a legitimate business. They have some arguments in their favor, which if put into force may result advantageously to the farmer. The classers they send out are well qualified. They handle a large quantity of cotton, so they can assemble large lots of even-running grade or staple, and can pool the whole and sell it to good advantage. Their storage facilities in the larger markets are excellent, and insurance rates are low.

The merchant furnishes the farmer with necessary supplies—food, everyday clothing, medicines, etc.—for his family, and also his tenants if he has any. The merchant is secured, in that the farmer must give him the first chance to buy the cotton when the bales are put on the market. This may appear to be a fair system, but it is one that has frequently wrought much hardship on the poor, hard-working farmer in the hands of a "Shylock" merchant.

Better means of transportation have increased competition among merchants, so that profits are not so excessive as formerly. Too, the prices paid for cotton are better than formerly. Competition between buyers is so keen that much cotton is handled on a very narrow margin. This has been brought about by better marketing conditions, an increase in number of buyers, especially itinerant representatives of large cotton dealers, and the development of cooperative marketing associations among the growers. Probably the worst defect of the present system is to be found in the lack of careful grading and stapling of cotton in some of the smaller markets. Not sufficient premium is paid for the better

grades and staple lengths to encourage the growers to produce them. Nor is any difference in character recognized. Practically as much is paid for cotton of an inferior character as is paid for good cotton.

*Trading in the Primary Market.*—There are usually one or more cotton gins at a primary cotton market, which is a small town, frequently a county seat. After getting a bale of cotton picked, the farmer may load it into his wagon early in the morning, haul it to town to have it ginned, and sell the bale while there. If there is no debenture against it, the owner may haul it to the



FIG. 110.—Cotton buying on the street. (Courtesy G. L. Meloy.)

local warehouse, have it sampled, get a receipt, and carry the sample around to the different buyers in town for bids. Or if there is no public warehouse in the town, he may haul the bale to the place where he can meet buyers and let them sample and bid (see Fig. 110). These buyers are usually either local men that have business connections with a firm of cotton buyers in a larger market, or are traveling representatives of some large firm. Both classes of buyers commonly buy on a "limit," a certain price specified by the firm they are buying for beyond which they cannot go. The firm bases this limit on the current market and notifies the local buyers one or more times during the day.

*Relation between Primary Market Prices and Values.*—It frequently happens in primary markets that, if competition for cotton is not keen and the grower is not well informed as to the value of his cotton, he will be given a price considerably below its actual worth. Taylor<sup>2</sup> investigated the variations in price paid for Middling cotton in the same market the same day in the different states of the Cotton Belt. It was found that there was a difference of at least \$2.50 a bale in every market listed. In one market the difference was \$15.60. The average difference was \$8.91.

In discussing the results of the investigation, Taylor says:

When such variations in prices as shown by this investigation, involving two or more bales of Middling grade, exist in any market, it is apparent that gross injustices may occur in many individual cases and in the aggregate assume enormous proportions. These variations show a condition that is unfair to the producer, for it is the farmer, ignorant of the value of his crop and knowing least about marketing his product, who as a rule is called upon to submit to such practices.

**Large Interior Markets.**—The cotton assembled and bought in the primary markets is mostly passed on to larger markets for classing and grouping bales in even-running lots. Of course, these markets vary in size. There is no well-defined line separating them from large primary markets, but some common points of difference may be pointed out. The larger market has a large warehouse and a compress, does a large volume of business, a goodly portion of which is in cotton collected in other markets, and has firms that sell either directly to mills or to consuming and export markets. Some of the firms in such markets may have connection or business relation with foreign firms and do some export business also.

A cotton firm in a large interior market must have considerable financial backing. It maintains an office in which market quotations are received several times during the day, and a force of classers that staple and grade the samples of cotton coming in and make up lots of even-running, or like, cotton (see Fig. 111). It has branch offices over its tributary territory, and business relations with a number of merchants who buy for the firm. The head office, on the basis of market reports determines the price to be paid, makes up lots of cotton for sale, and makes sales. As a rule, too, the head office protects the business from loss that might come from a fall in the market, by "hedging." This is a

sort of price insurance secured by buying or selling cotton on the future exchange market, the details of which will be explained later.

Charlotte, N. C.; Spartanburg, S. C.; Macon, Ga.; Montgomery, Ala.; Greenwood, Miss.; Pine Bluff, Ark.; Shreveport, La.; and Fort Worth, Tex. are illustrative of the type of markets just described. There are several such markets in almost all of the cotton-producing states.



FIG. 111.—Well-lighted room for classing cotton, and the display of samples for the inspection of buyers. (*Courtesy U. S. Department of Agriculture, Bureau Agricultural Economics.*)

**Consuming Markets.**—Certain cities in which or near which there are a number of cotton mills are known as consuming markets, because much cotton is brought there for actual consumption. Boston, New Bedford, Fall River, New York, and Philadelphia are the leading consuming markets in the Northeast, while Charlotte, Greenville, Spartanburg, and Gastonia in the Carolinas, and Atlanta, Ga., are important markets in the South. In these markets are a number of spinners' brokers, men who know the particular kind of cotton desired by certain mills

and make a specialty of finding and buying for the mills. There are also to be found in such markets selling brokers, who represent large cotton-buying firms in the larger markets of the South.

**Export Markets.**—The leading export markets of the United States, in order of rank, are Galveston, New Orleans, Savannah, and New York. Much of the cotton handled in these cities is bought and consigned by interior markets, but must be routed through export markets.

**Foreign Markets.**—Liverpool is the leading cotton market of the world. This market handles not only a large part of the American cotton that is exported, but also cotton from nearly every producing country in the world. Manchester is another English market of importance. Havre is an importing market in France, Antwerp and Ghent in Belgium, Rotterdam in Holland, Bremen in Germany, Barcelona in Spain, and Genoa in Italy. Japan also takes a large quantity of American cotton.

**Future Markets.**—There are future markets at Liverpool, Bremen, Havre, New York, New Orleans, and Chicago. Trading in futures on the Chicago market began only recently. These markets deal in contracts for the delivery of cotton at some specified future date. Most of the sales or purchases are for the purpose of "hedging," or for speculation, and only a small percentage of the cotton sold is actually delivered. The figures for the New York Exchange, as given by Hubbard,<sup>1</sup> show that in some years as small a quantity as 85,400 bales is delivered, whereas in other years it ranges as high as 1,005,300 bales.

**Value of the Future Markets to the Cotton Trade.**—Although the future exchanges are frequently criticized and a part of the trading done there is purely speculative, they are of great value to the cotton industry. The exchanges establish market prices which are largely based on the supply or prospective supply and demand for cotton. By means of the quotations sent out, the market of the whole world is unified. The exchanges serve to regulate prices and afford legitimate business an insurance against loss from market changes. How the protection is secured will now be described. Suppose that a spinner sells a large bill of cotton goods to be delivered in 6 months. He at once buys of a cotton merchant a sufficient number of bales of cotton to make the goods. The merchant, to protect himself against a change in the price of cotton prior to the time for delivery, buys an equivalent amount of cotton on the future exchange, or "hedges."

as it is termed, at a price in keeping with the terms of the present sale. If, when the time for delivery arrives, the price of cotton has advanced so that the actual bales he buys in the market to fill the order cost him more than the price stipulated in the sale, there will be a loss; but if he bought "future" cotton, the price of that will have advanced so that there will be a gain on his "futures" sufficient to balance the loss on the other, or approximately balance it. In actual deals, the balance may go one way in one trade and the other in the next. The original sale price was, of course, fixed so that there would be some net profit. If, in the illustration just given, the market had declined, the merchant would have been able to buy cotton in the open market at a lower price than the one stipulated in his sale. This would give him profit, but there would be in that case a loss on the "future" cotton to balance the extra gain.

Dealers on the future exchanges keep close watch on the consumption of cotton in all parts of the world and the growth conditions in the producing countries. By this means they hope to anticipate the market and buy or sell to their advantage. This study, however, helps keep the market prices based on supply and demand. The quotations of sales as they are made are studied closely by dealers in all parts of the Cotton Belt.

**Market Prices.**—The basis for price quotations in all markets is the quotation for Middling cotton on the future exchanges. Exchange quotations are for short-staple cotton of a length not below  $\frac{7}{8}$  inch. The values of grades above and below Middling fluctuate somewhat, relatively, the fluctuation depending on supply or demand for particular grades and staple lengths. The values quoted for the different grades are determined largely by the values given for actual sales made in the designated spot cotton markets of the country. These markets, which were selected by the Secretary of Agriculture, are Norfolk, Augusta, Savannah, Montgomery, New Orleans, Memphis, Little Rock, Dallas, Houston, and Galveston. In each city there is a committee, approved by the U. S. Department of Agriculture, which makes a daily survey of the market and reports to the Department of Agriculture and the cotton exchanges of the country market values of different grades of cotton in that market on the day specified. Some illustrative figures will be given in a later paragraph.

The buyer in a particular locality, in determining the price he can afford for cotton that he buys, considers first the future

market price for cotton, the relation of spots and futures existing at the time, then the relative value of the different grades and staple lengths, the freight charges if the cotton has to be moved at his expense, insurance and storage charges, and some profit in return for his labor and capital used.

The range of prices paid for spot cotton in the New York market for a long series of years (1829 to 1921) is shown by Fig. 112.

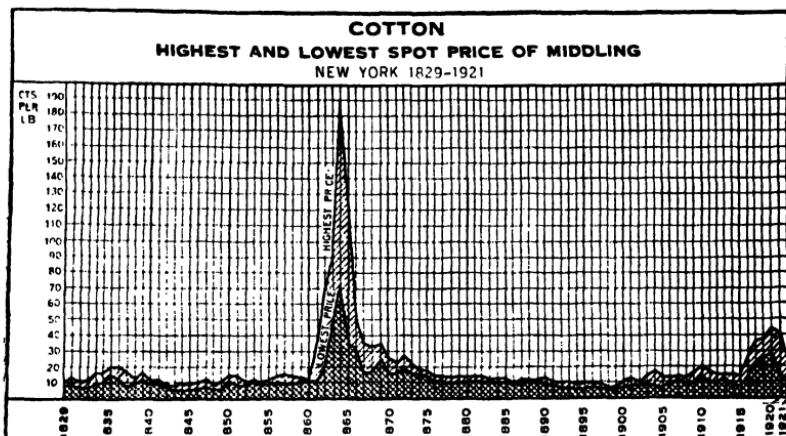


FIG. 112.—In the period of the recent war the price did not rise as high as in the Civil War period, one reason being that production continued and there was always available a good supply, whereas in the earlier period very little was produced and almost no cotton was available. (*Year Book, U. S. Department Agriculture*.)

**Marketing Period.**—A large percentage of the small farmers and tenant farmers who grow cotton have debts to settle and are required to sell their cotton soon after it is ginned to pay the debts. The negro tenants, even if they have no debts to settle, almost all want to sell at once so that they may have money to spend. Many of the growers have no satisfactory place to store their cotton after ginning. On account of these conditions and for other reasons, the bulk of the cotton grown passes out of the hands of the growers a few weeks after ginning. Figure 113 shows graphically the percentage of cotton sold each month in the year. It will be noticed that 75 per cent of the cotton is sold by the end of January.

Some of the larger growers, especially the ones who are well conditioned financially, make it a practice to hold their cotton for

## COTTON

NUMBER OF BALES MARKETED BY MONTHS AND  
AVERAGE FARM PRICE, FIRST OF EACH MONTH  
AVERAGE, 1910-11 TO 1914-15

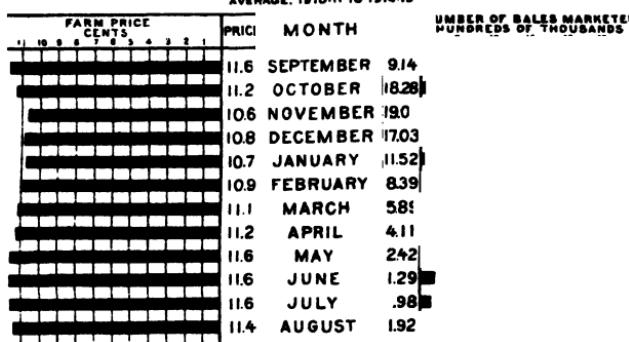


FIG. 113.—The producers sell most of their cotton in the heaviest ginning season, September to January. The monthly average price for the five years, September, 1910, to August, 1914, was lowest in November and highest in May, June, and July. (After Taylor.)

COTTON  
MOVEMENTS

QUANTITY AND PERCENTAGE OF THE TOTAL CROP GINNED,  
IN STORAGE, EXPORTED AND CONSUMED, BY MONTHS

1913-1914

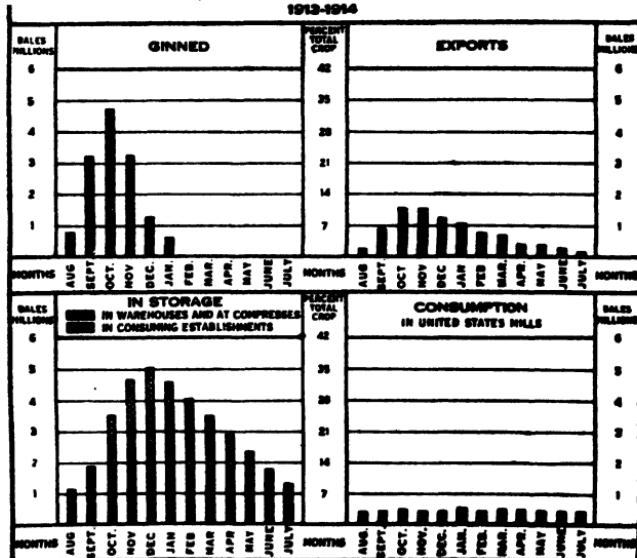


FIG. 114.—Ginning begins in July and ends in February or March. October is the busiest month. Averaging 1913-1914 and 1914-1915, by months, the amount in storage increased from August to December and then gradually declined, not reaching above 36 per cent of the total crop. The heaviest export movements were from September to January, during the heaviest ginning season. Mills consumed regularly, and had on hand at the end of the year only enough cotton to supply them for about two months running. (After Taylor.)

a while, or at least a part of it, if the market is not satisfactory at ginning time.

The placing of a large amount of cotton on the market at one time has a tendency, as may be readily seen, to glut the market and to depress the price. Figure 113 shows the relation of farm prices and number of bales sold.

Although most of the cotton soon passes out of the hands of the producers, it is, as a rule, taken by the mills gradually throughout the year. In the meantime it is stored in warehouses and large public storage places, and owned by cotton dealers, traders, etc. (see Fig. 114).

**Orderly Marketing.**—The present trend of the cotton producers is away from dumping the crop on the market during or soon after the ginning season, and toward the goal of orderly marketing, which means the sale of cotton throughout the year as needed by the consumers. This change is being brought about by the diversification in crops grown, which makes the growers less dependent on merchants for supplies, and by the development of cooperative marketing associations among the growers.

*Cooperative Marketing Associations.*—A good many cooperative marketing associations for the marketing of cotton have been organized and tried, but most of them have not been successful. Organizations formed more recently not only for selling cotton but for selling other commodities cooperatively are meeting with greater success. Probably something has been gained from the former failures, so that pitfalls are being avoided. For a cooperative association to be a success, the individual must make some sacrifice at times for the benefit of the whole. To do this requires a high standard of ethics. Americans are so used to personal independence and to doing as they please that they are naturally not well fitted for cooperative movements.

One of the most successful of the cotton cooperative marketing associations that have been formed is the Staple Cotton Cooperative Association of Mississippi. This organization has as members about 2,000 growers of Upland staple cotton. The organization was formed by growers of staple cotton in the Yazoo-Mississippi Delta of the state of Mississippi, but is open to membership to growers of staple cotton in other states, and at present includes members in some of the neighboring states.

It was the purpose of the members in making the Association to secure a more efficient and satisfactory system for marketing their cotton. Speculative features were not contemplated and there was no intention to try to "bull the market," or raise the price of staple cotton by holding cotton. It was the intent simply to supply the consumer with well-classed cotton at a fair market price.

The Staple Cotton Cooperative Association has a board of directors consisting of twenty-one members chosen from among the leading growers of staple cotton in the district, a general manager, an assistant general manager, a secretary-treasurer, a force of expert classers, and managers of branch offices at principal concentration points in the Delta. The head business office is situated at Greenwood, Miss.

The general manager spends much of his time studying the cotton market, and in visiting the leading consuming markets of the world where he secures business agreements and makes sales.

In the usual workings of the organization the member delivers his cotton at the nearest concentration point where there is a good warehouse. The bales are sampled and samples forwarded to the nearest branch office. The branch office issues a receipt for the tentative classing on each bale. The grower can borrow through the Association, on the basis of this tentative classing sheet, money on his cotton to the extent of about 80 per cent of its value. A comparatively low rate of interest is paid for this money during the time it is charged against the borrower. During the season 1924-1925 the rate was  $4\frac{1}{2}$  per cent. The samples are then sent to the main office, where they are classed carefully by the expert classers there and a classing sheet is rendered the grower. This sheet shows the grade, staple length, and character of each bale received. The bales are grouped in even-running lots in respect to staple length, grade, character, etc., and pools are made up for sale. Cotton from these pools is sold on the market during the year at the best price obtainable. No future or speculative sales are made. Statistical reports, showing sales made, quantity of cotton on hand, etc., are made to the members each month. Checks are also sent to them each month covering their pro-rata shares of the sales made during the month.

It appears that the Staple Cotton Cooperative Association has been able to render a definite service to its members. Their

cotton is stored in a good warehouse at a reasonable cost, and is insured at a rate lower than the individual can secure. It is carefully stapled and graded and a classing sheet is rendered, so that the owner may know within narrow limits just what the cotton is worth. It is pooled in large even-running lots, so that the best possible market price can be obtained. The individual with a small lot cannot command so high a price. The average price received is higher than that which could be obtained by individuals. Only the actual cost of handling and selling is charged against the cotton. The middleman's profit is eliminated. Sales are made during the year as the market demands. The depression of price from a glutted market, such as comes regularly when a large quantity of a commodity is thrown on the market at once, is avoided.

Some criticisms are directed against the Association, the principal ones being that cotton is not sold while the price is high, no advantage being taken of the spurts in market which the individual grower might make use of; and that the member has to wait a long time for his money. While some of the criticism may be just, much of it is not well grounded and is the result of propaganda put out by rival business concerns.

It is claimed that the Association has a tendency to stabilize staple cotton prices and make better prices available both for members of the Association and for growers without. During the season of 1924-1925 the Association handled 124,852 bales of cotton.

*Other Cooperative Cotton Associations.*—Within the past few years cooperative cotton associations for selling short-staple cotton have been organized in Arkansas, Mississippi, Tennessee, and several other states. In 1923, there were thirteen associations, which handled 800,000 bales of cotton. The objects and methods of these are similar to those of the Staple Cotton Cooperative Association. Whether or not they will be permanent remains to be seen. For them to be a success they must render to the public a service as efficient as that now given by private concerns and at a rate as low.

**Warehousing Cotton.**—The U. S. Department of Agriculture has estimated that the annual loss due to exposure of cotton bales to the weather is more than \$30,000,000. The storage of cotton, immediately after ginning, in a good warehouse, prevents weather damage practically altogether. There are also other

advantages to be gained from warehouse storage. If the warehouse is a first-class one, insurance rates will be moderate, and the warehouse receipt may be used as security in negotiating loans. Receipts from warehouses licensed in accordance with the United States Warehouse Act of 1916 are accepted by banks everywhere as negotiable paper.

**Selling Cotton in the Seed.**—In the extreme northern part of the Cotton Belt and in other parts where gins are not numerous, a considerable quantity of cotton is sold without ginning, or "sold in the seed," as it is termed. A higher percentage is marketed in this way in Virginia, Missouri, Oklahoma, Florida, and Tennessee than in other states. In 1915, 8.5 per cent of the crop of the country was sold in the seed, the total amounting to 937,000 bales.

Selling cotton in the seed usually works to the disadvantage of the producer. Before the cotton is ginned, no one can grade it accurately, and consequently the ginner in his estimate of the grade is careful to give himself some margin. Frequently, several lots of cotton are put together in one bin, with the consequent mixture of different grades and staple lengths. The grower of cotton with good staple length or of high grade, is apt to get little or no premium over that obtained by the grower of the most inferior cotton. The net result is that the growers are encouraged to grow inferior varieties that will yield plenty of seed cotton.

In communities where most of the cotton is sold in the seed, the grower who tries to grow a good variety and market lint and seed separately is placed at a disadvantage, because, since there is not much cotton sold in the bale in that market, regular buyers do not visit the market. The buyers of the gin-run cotton may not grade the cotton at all before making the purchase, and, of course, the price is low.

**Damaged and Inferior Cotton.**—In the course of marketing 10,000,000 to 15,000,000 bales of cotton a considerable quantity of damaged or inferior cotton is found. This is the result of leaving the cotton in the field too long before picking, faulty ginning, improper care of bales after ginning, carelessness in the transportation of bales, and several other factors.

*Country Damage.*—A bale of cotton is considered a non-perishable product, and if stored properly, will last for years with but little deterioration. Bales may be left out in the rain or exposed to the weather without protection for a longer period

than most agricultural products without serious damage. But even cotton bales will be injured by the weather, and the total loss to growers in consequence amounts to millions annually.

It has been, and still is to some extent, the practice of some growers to haul bales of cotton home from the gin and throw them on the ground or perhaps put them on poles in some convenient place. Often a considerable quantity is stored in a similar way around gins or about concentration points in towns during the rush of the ginning season. If cotton is left exposed in this way for a few weeks, the bagging becomes bleached and the exposed cotton discolored, the bale appearing to be damaged even if it is not. If the bale rests on the ground, the lint coming in contact with the soil will be discolored, and if there are rains, moisture from the ground is apt to penetrate the bale for a considerable distance, causing a weakening, discoloration, or even a rotting of the fibers. Half of the bale may be ruined in this way. When the bales are put on poles, water is apt to run under them and wet them where they come in contact with the poles. The cotton may mildew in these places if the bales are not turned after rains, so that they will have a chance to dry out.

*Transportation Damage.*—Cotton is sometimes damaged to some extent through getting wet while stored on railway platforms and in leaky cars, and by the water from rivers when the bales are piled on boats near the water line. A goodly portion of the apparent transportation damage is really not the result of injury during transit, but is due to wet cotton being accepted for carriage with the resultant damage appearing during transit or at the end of the journey.

*Pickings.*—A bale of cotton that has become damaged is not in a marketable condition. Before it can be marketed satisfactorily, it must be worked over, or "conditioned," as it is termed. The bale is opened and all damaged cotton is carefully separated from the rest by hand. The lint of the bale may be sorted out into two or three lots, the number depending on quality, and later rebaled with cotton from other similar bales. Cotton from "pickeries" is usually irregular and of low grade. Its value is not quoted in the market.

*Repacked Cotton.*—Repacked cotton is also known as "loose cotton," or "the city crop." It consists of samples from cotton-classing rooms and brokers' offices, which have been collected and rebaled.

Since every bale of cotton is sampled one or more times, frequently several times, the aggregate of lint cotton in these samples is considerable. Allowing 1 pound to the bale, which appears to be a reasonable estimate, the whole amount for a 14,000,000-bale crop is equivalent to 28,000 bales.

*Cotton of Perished Staple.*\*—Cotton of perished staple is defined by the U. S. Department of Agriculture<sup>3</sup> as cotton that has had the strength of fiber, as ordinarily found in cotton, destroyed or unduly reduced through exposure to the weather either before picking or after baling, or through heating by fire, or on account of water packing, or by other causes.

*Cotton of Immature Staple.*—Cotton of immature staple is cotton that has been picked and baled before the fiber has reached a normal state of maturity. This results in a weakened staple of inferior value.

*Gin-cut Cotton.*—Gin-cut cotton is defined as cotton that shows damage in ginning, through cutting by the saws, to an extent that reduces its value more than two grades.

*Reginned Cotton.*—Reginned cotton is cotton that has passed through the ginning process more than once and, after having been ginned, has been subjected to a cleaning process and then baled.

*False-packed Cotton.*—False-packed cotton is defined as cotton in a bale (1) containing substances entirely foreign to cotton, (2) containing damaged cotton in the interior, with or without any indication of such damage upon the exterior, (3) composed of good cotton upon the exterior and decidedly inferior cotton in the interior, arranged in such manner as not to be detected by customary examination, called a plated bale, or (4) containing pickings or linters worked into the bale.

*Mixed-packed Cotton.*—Cotton is considered mixed-packed if the cotton in a bale shows a difference of more than two grades in samples drawn therefrom, or shows a difference in color exceeding two grades between such samples.

*Water-packed Cotton.*—Cotton is considered to be water-packed if the cotton in the bale has been penetrated by water during the baling process, causing damage to the fiber, or if, through exposure to the weather or by other means, while apparently dry

\* This type of cotton and the following kinds of irregular cotton are defined by the Secretary of Agriculture in regulations under the United States Cotton Futures Act.

on the exterior, the cotton on the interior of the bale has been damaged by water.

**Cotton Not Tenderable on a Future Contract.**—The different types of inferior cotton mentioned in the preceding paragraphs, cotton with a staple length less than  $\frac{7}{8}$  inch, and the lower grades of cotton cannot be offered in settlement of a future contract. The following paragraph from the Cotton Futures Act, as amended Mar. 4, 1919, specifies the types of cotton that may not be delivered.

Fifth. Provided that cotton that, because of the presence of extraneous matter of any character, or irregularities or defects, is reduced in value below that of Low Middling, or cotton that is below the grade of Low Middling, or, if tinged, cotton that is below the grade of Strict Middling, or, if yellow-stained, cotton that is below the grade of Good Middling, the grades mentioned being of the Official Cotton Standards of the United States, or cotton that is less than  $\frac{7}{8}$  inch in length of staple, or cotton of perished staple, or of immature staple, or cotton that is "gin cut" or "reginned," or cotton that is "repacked" or "false-packed" or "mixed-packed," or "water-packed," shall not be delivered on, under, or in settlement of such contract.

**Relative Value of Different Grades of Cotton.**—As was mentioned previously, the price of Middling cotton—is the basic price. The values of other grades are usually expressed as so many points "on" or "off" Middling price. A point is one-hundredth of a cent. "On" means above the price of Middling, while "off" means below. The ten designated spot markets quote the value of the different grades, their quotations being based on values in actual sales. Averages made from their quotations are used for the values of the different grades in future contract settlements when deliveries are made.

Table XXXVII shows the values of all of the different grades of both white and discolored cotton in the leading spot markets on a certain day.

**Value of Various Staple Lengths of Upland Cotton.**—Cotton shorter in staple length than  $\frac{7}{8}$  inch is not acceptable in the settlement of a future contract and is not quoted on the market regularly. Cotton  $\frac{7}{8}$  to 1 inch in length is considered short cotton, and very little if any difference in price is made for different lengths between these limits. Above 1 inch, there is an extra premium paid for each  $\frac{1}{16}$ -inch increase in length.

TABLE XXXVII.—GRADE DIFFERENCES REPORTED BY TEN IMPORTANT SPOT MARKETS\* ON JULY 31, 1922 (After Palmer)

Market	White standards		Yellow-stained		Blue-stained	
	Middle fiber, on	Starter good middle, on	Middle, on	Starter low middle, on	Middle, on	Good middle, on
Norfolk	200	150	100	50	21.38	50
Augusta	125	100	75	38	21.38	37
Savannah	125	100	75	50	21.22	50
Montgomery	163	125	88	50	21.19	50
New Orleans	175	150	100	50	21.25	50
Memphis	225	150	100	50	22.36	50
Little Rock	200	150	100	75	21.50	50
Dallas	200	150	100	75	21.39	75
Houston	150	125	100	50	21.70	75
Galveston	250	175	100	50	21.75	75
Average	181	138	94	54	21.51	56

\* The average differences of these ten markets are used in settlements for cotton delivered on future contracts of the New York Cotton Exchange, the markets being designated for the purpose by the Secretary of Agriculture under authority of the United States Cotton Futures Act.

Table XXXVIII gives premium paid over short cotton for different staple lengths in the leading staple cotton markets, New Orleans and Memphis, on a certain date each year for four successive years. The premiums for 1920 were abnormally high, whereas those of 1923 were unusually low.

TABLE XXXVIII.—A COMPARISON OF STAPLE PREMIUMS QUOTED IN TWO LARGE MARKETS FOR STAPLE COTTON

	Apr. 30, 1920		Apr. 30, 1921		Apr. 29, 1922		May 5, 1923	
	New Orleans	Memphis	New Orleans	Memphis	New Orleans	Memphis	New Orleans	Memphis
Middling Upland short cotton, cents <sup>a</sup> .....	41.00	42.00	11.25	11.00	17.00	17.25	26.50	27.50
	Points	Points	Points	Points	Points	Points	Points	Points
	on	on	on	on	on	on	on	on
1 <sup>1</sup> <sub>4</sub> inches.....	625	600	100	150	150	175	50	Even
1 <sup>1</sup> <sub>4</sub> inches.....	2,425	2,600	200	400	375	375	100	120
1 <sup>3</sup> <sub>16</sub> inches.....	3,550	4,000	525	700	550	575	150	150
1 <sup>5</sup> <sub>16</sub> inches.....	4,200	4,600	800	b	800	875	225	250
1 <sup>5</sup> <sub>16</sub> inches.....	b	5,000	b	b	b	b	300	b
1 <sup>3</sup> <sub>8</sub> inches.....	b	5,850	b	b	b	b	400	b

<sup>a</sup> Cotton Exchange spot quotation. <sup>b</sup> Nominal.

**Regional Names and Values.**—The varieties grown and the soil and climatic conditions affect the quality of cottons produced in different regions. This has led buyers and merchants to use certain trade names for cotton from particular regions, as, for instance, Mississippi Deltas, Texas-Oklahoma cotton, Red River Staples, Carolina Staples, Mississippi Hill Cotton, or North Georgias, etc. In each these regions more than one variety is grown and the cotton is not altogether uniform, but there is enough similarity to give it some uniformity of character, sufficient to cause the trade to take notice of it. A premium of a cent or more a pound may be paid for cotton from a certain region over that from another region which has cotton of the same grade and staple length. In the regular sales, cotton is, of course, sold on the basis of the grade and staple length. The regional name is used in addition to give some notion of the character of the cotton.

The following paragraph from Palmer<sup>4</sup> gives something of the history and meaning of special names that have been used by the cotton trade, some of which are still in use:

In early days in the New Orleans and Memphis markets, cotton was known as "Staples" or "Peelers," "Benders," "Rivers," and "Creeks."

"Staples," or "Peelers," were the long-staple varieties from the Yazoo and Mississippi Delta plantations. "Binders" referred to cotton of extra length and character which the river boats took up from the plantations in the bends of the river where the soil was extremely rich. "Rivers" were the hard-bodied cottons from the plantations along the Mississippi and its tributaries, and the "Creeks" the slightly softer cottons from along the smaller streams where there was less bottom land. "Uplands" was originally the term used to describe short cotton from the hill section, but gradually it has come to mean in this country all of the crop of the United States except Sea Island and American-Egyptian varieties.

TABLE XXXIX.—COMPARISON OF THE RELATIVE PERCENTAGE OF SPINNABLE COTTON REMAINING AFTER ELIMINATING THE VISIBLE WASTE  
CONTENT IN CERTAIN STANDARDIZED GRADES WITH THEIR  
RELATIVE VALUE ACCORDING TO COMMERCIAL DIFFER-  
ENCES (*After Palmer*)

(Average of Ten Important Spot Markets)

Grade	Relative percentage of spin- nable cotton <sup>a</sup>	Relative value according to com- mercial differences, per cent			
		May 15, 1916	July 17, 1920	July 31, 1922	July 31, 1923
Middling Fair.....	102.4	107.6	101.6	108.4	104.2
Good Middling.....	101.6	103.8	106.3	104.4	103.1
Middling.....	100.0	100.0	100.0	100.0	100.0
Low Middling.....	98.6	94.1	78.8	94.2	96.9
Good Ordinary.....	95.9	86.2	61.6	85.9	92.0
Good Middling yellow- tinged.....	99.8	99.8	94.8	100.1	98.3
Middling yellow-tinged...	98.5	96.3	86.9	92.8	95.8
Low Middling yellow- tinged.....	94.5	90.2	72.2	85.6	91.3
Good Middling yellow- stained.....	100.0	96.0	88.1	94.2	97.0
Middling yellow-stained..	95.8	92.2	79.1	85.9	92.2
Good Middling blue- stained.....	99.6	95.5	85.1	93.6	95.7
Middling blue-stained....	96.4	90.5	77.0	86.3	92.1

<sup>a</sup> Computed from percentages of waste as determined in spinning tests conducted by the department. See *Bulletin 591, "Manufacturing Tests of the Official Cotton Standards for Grade,"* by William S. Dean and Fred Taylor, and *Bulletin 990, "Preliminary Manufacturing Tests of the Official Cotton Standards of the United States for Color for Upland Tinged and Stained Cotton,"* by W. R. Meadows and W. G. Blair.

**Relation of the Percentage of Spinnable Cotton in the Different Grades and Their Market Value.**—The question frequently arises as to whether or not premiums paid for cotton better than Middling or discounts made for cotton of lower grade than Middling are just or are in proportion to their spinning values. Table XXXIX, from Palmer,<sup>4</sup> shows relation of market values of different grades of cotton in ten important spot markets, and their

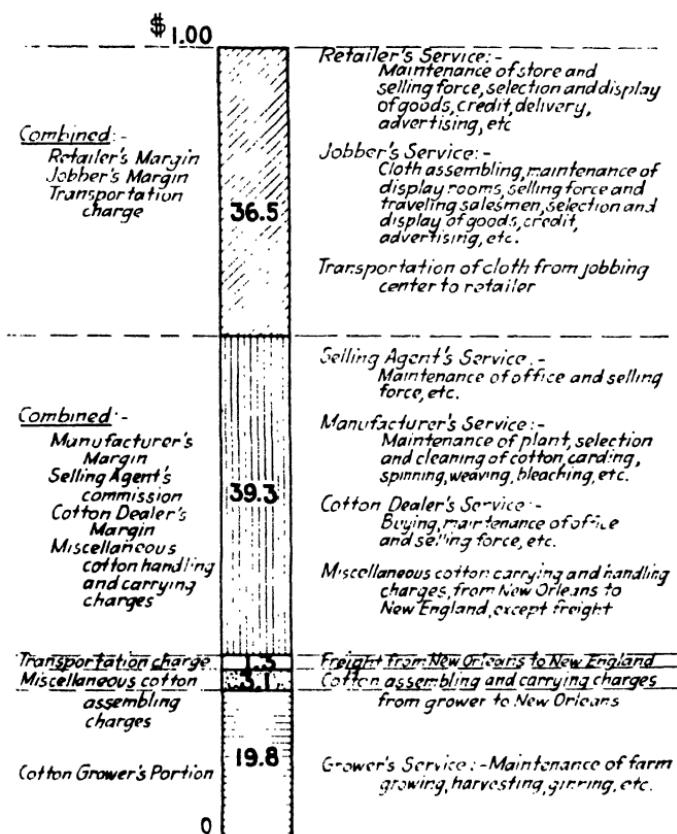


FIG. 115.—Division of consumer's dollar spent for sheeting in 1922.

spinning values as shown by results from spinning tests conducted by officials of the U. S. Department of Agriculture. Both premiums and discounts are apparently somewhat in excess. However, spinning values are determined in part by qualities other than grade of cotton (see Chap. VII for further discussion of spinning qualities).

**Relation of the Market Price of a Pound of Raw Cotton and the Retail Price of the Goods Made from It.**—Several yards of

cotton goods may be made from 1 pound of raw cotton. Under the prevailing high retail prices of cotton goods, it may appear at first thought that the grower is not getting his share of the money that the consumer pays for goods, but a study of the many items of expense between the bale of cotton and sale of a dress pattern to the consumer convinces one that the grower is not so badly mistreated as it at first appeared. The consumer does pay several times as much for the pound of cotton as the grower receives, but a good deal of the extra price is for fancy showrooms, expenses of traveling men, losses due to changes in fashions, advertising, etc. Items of expense must be added to the retail price of the goods and paid by the consumer; yet they add very little or nothing to the real value of the goods.

L. A. Adams, Marketing Specialist of the U. S. Department of Agriculture, has made an analysis of the difference between the retail price of cotton cloth and the price of raw cotton. Figure 115, taken from his report, shows the distribution of the dollar which the consumer spends for sheeting.

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## CHAPTER XX

### COTTON EXCHANGES

Exchange means to give or trade one value on commodity for another. The word "exchange" is also used as a name for the place where exchanging or trading is taking place. Nearly every town or city has a "cotton exchange," or a place where men meet to buy and sell cotton. Many of these trading places are not called exchanges, but are simply a street or part of a street where traders, through habit or for some reason, have become accustomed to meet. In some instances the trading place or exchange is located by a municipal ordinance. Trading is open to everyone in these simple markets. There are no regular members and no rules except the rules of custom. As the business increases, it becomes necessary to have certain definite rules to protect the rights of individuals and help make the business run smoothly. For the convenience of the traders it is also helpful to have a limited membership—have as traders only men who have established a reputation of moral integrity and are responsible financially.

It seems that it is natural for most men to like to trade. The small boy trades tops and marbles largely for the pleasure of the exchange. David Harum traded horses for the fun of the game. There is a fascination about buying and selling cotton which draws many to it. Many fortunes have been made in the cotton trade, but, unfortunately, a good many have been lost. For a cotton trader to succeed he must not only "know" cotton, but must be a good business man.

**The Evolution of Cotton Exchanges Where Future Contracts Are Bought and Sold.**—Prior to 1818, there were no telegraph or cable lines and no railroads, and no steamboat had crossed the Atlantic. Means of communication, measured by modern standards, were very poor. Under such conditions trading in cotton as practiced today was not possible. In 1819, the first steamboat crossed the Atlantic Ocean. From this date on during the next half century means of communication were gradually

improved. A steam railway line was put in operation in 1829, the telegraph in 1844, and the Atlantic cable in 1866.

With the improvement of means of communication came the development of trading in future contracts in the cotton exchanges. It is always the desire of cotton merchants, farmers, and mill men to play safe, or to insure their investments when they can conveniently. When the opportunity to do so by means of "futures" arose, they made use of it. According to Hubbard,<sup>1</sup> the first step toward our present system of "futures" was the selling of "cotton afloat," which was practiced a decade or two prior to 1866. The cotton bales were sampled before being stored on board a ship in the American port. The samples were then placed on fast-sailing ships, which reached Liverpool considerably sooner than freighters bearing the cotton bales. Brokers in Liverpool examined these samples when they arrived and bought the "cotton afloat," or "to arrive," on the basis of the samples. With the completion of the Atlantic cable in 1866, market reports from America were received in Liverpool daily or more frequently. This made the old plan of selling by sample "cotton to arrive" unsatisfactory. When market reports are received often, so that buyers can keep posted on market prices at all times, immediate sales contracts are desired. A new scheme was devised to take the place of the old "cotton afloat" sales. According to the new plan, cotton from the United States was sold on Middling basis, no samples being used, no grade specified except the cotton was not to be below Middling, and no particular ship on which the cotton was to arrive being mentioned. It was to be delivered within a certain two-month period. This form of sale was, as may be seen, of a more general nature than the former, and was better liked by both merchant and spinner, since it gave greater latitude. The plan resembles rather closely our modern system of "futures."

During the Civil War in America "cotton to arrive" was bought and sold in New York. This was probably the first step toward the development of future exchanges in America.

The origin of future exchanges was discussed by Arthur R. Marsh, a former vice-president of the New York Exchange, in his address before the National Association of Cotton Manufacturers at Washington, D. C., in 1907. Portions of this address, as quoted by Miller,<sup>2</sup> are as follows:

Before the Civil War the cotton business in New York was simply one form of the old-fashioned commission business, exactly like the business of handling molasses, sugar, hides, wool, country produce, and many other similar agricultural commodities.

The Civil War completely upset the conduct of the cotton business in New York, as just described. While it lasted, there were, of course, no regular shipments of cotton to New York from the South, and the only source of supply consisted of lots of cotton which the government from time to time got hold of through the capture of blockade runners or through confiscation in the South. Naturally, such lots of cotton could not be handled on a commission basis, but had to be bought outright as a speculation. The huge profit made by some of those who bought this Government cotton was the real beginning of general speculation in cotton in this country. And the same thing happened across the water in Liverpool. The fierce demand and the uncertain and inadequate supply gave opportunity for vast and sudden profits, such as have never been seen before or since in connection with any commodity. And, curiously enough, it was out of this wild speculation of the time of the Civil War that the entire modern method of handling the cotton business was evolved; for, in their eagerness to get hold of cotton, speculators began to buy not only actual cotton on the spot in New York or Liverpool, but "cotton to arrive," when they got wind of a lot of cotton on some ship destined for one or the other of those ports. Here was the beginning of the system of trading in cotton futures, which has gradually revolutionized the whole cotton business in every root and branch, for very clever men, whose business was that of cotton merchants and not speculators, saw a way to make use of the extensive trading in contracts for "cotton to arrive" as a protection to themselves in their legitimate buying and selling actual cotton.

It was two or three years after the Civil War that this new conception of the cotton business took shape in the mind of one of the most brilliant cotton merchants the world has ever known, the late Mr. Rew, of Liverpool, whose firm is still in existence. In 1868 or 1869, Mr. Rew saw that the newly laid Atlantic cable made it possible for a cotton merchant in Liverpool to ascertain with unheard-of quickness the price at which actual cotton could be bought in the Southern States, and the approximate date at which it could be shipped to England. He saw also that, if the price that was being bid in Liverpool for "cotton to arrive" was high enough to enable him to buy the cotton in the South and sell contracts for this same "cotton to arrive" in Liverpool, two or three months later, he could enter into the transaction with entire safety, as when his cotton reached Liverpool he could either deliver it to the parties to whom he had sold the contract, or if some spinner was willing to pay a higher relative price than the holder of the contracts had

agreed to pay, he could back his contracts and sell the cotton to the spinner with the larger profit to himself.

Following the successful venture of Mr. Rew, other buyers in Liverpool and elsewhere began to deal in contracts for future delivery of cotton. The New York Cotton Exchange was organized and began trading in "futures" in 1870. The New Orleans Cotton Exchange was organized in 1871, and the Liverpool Cotton Association adopted rules governing "future" trading the same year.

**Spot Cotton and Future Contracts.**—Before proceeding farther in the discussion of cotton exchanges, it may be well to explain more fully the distinction between "Spot cotton," or "Spots," and "Future Contracts," or "Futures."

"Spot cotton," or "spots," which is simply a contraction of the term, includes all cotton that is bought or sold except that sold on future contracts in cotton exchanges. The latter is "futures," or "future contract cotton."

The term "spot cotton" was at first applied to actual cotton in a warehouse, piled up at a port, or actually on the spot in the market. The term is also used for cotton being shipped, or *en route*, to the market, or to cotton that will be shipped at some future date. As brought out by Hubbard,<sup>1</sup> it is not altogether correct to designate "spot cotton" as simply actual cotton and "futures" as fictitious cotton. A dealer may sell spot cotton for future delivery, cotton that he does not have but expects to purchase and deliver. On the other hand, a trader who sells "futures" may deliver the actual bales of cotton at the expiration of the contract period. This may be somewhat confusing to a person beginning the study of the subject, but the matter may be clarified if it is remembered that all cotton sold is "spot cotton" except that sold on future contracts in exchanges.

**New York Cotton Exchange.**—At present there are six cotton exchanges that deal in future contracts—New York, New Orleans, Chicago, Liverpool, Bremen, and Havre. The operation of all of these is similar. A discussion of the New York Exchange will, therefore, suffice, in a general way, for all.

The New York Cotton Exchange was organized at first simply as a means of convenience for the people in New York who were engaged in buying and selling cotton. There were many cotton traders scattered about over the city who dealt in both "spot cotton" and "futures." To reach these traders, or for them to

reach each other, it was necessary to do much traveling about over the city, and to do much waiting for men that happened to be out of their offices. As the trading business increased, the

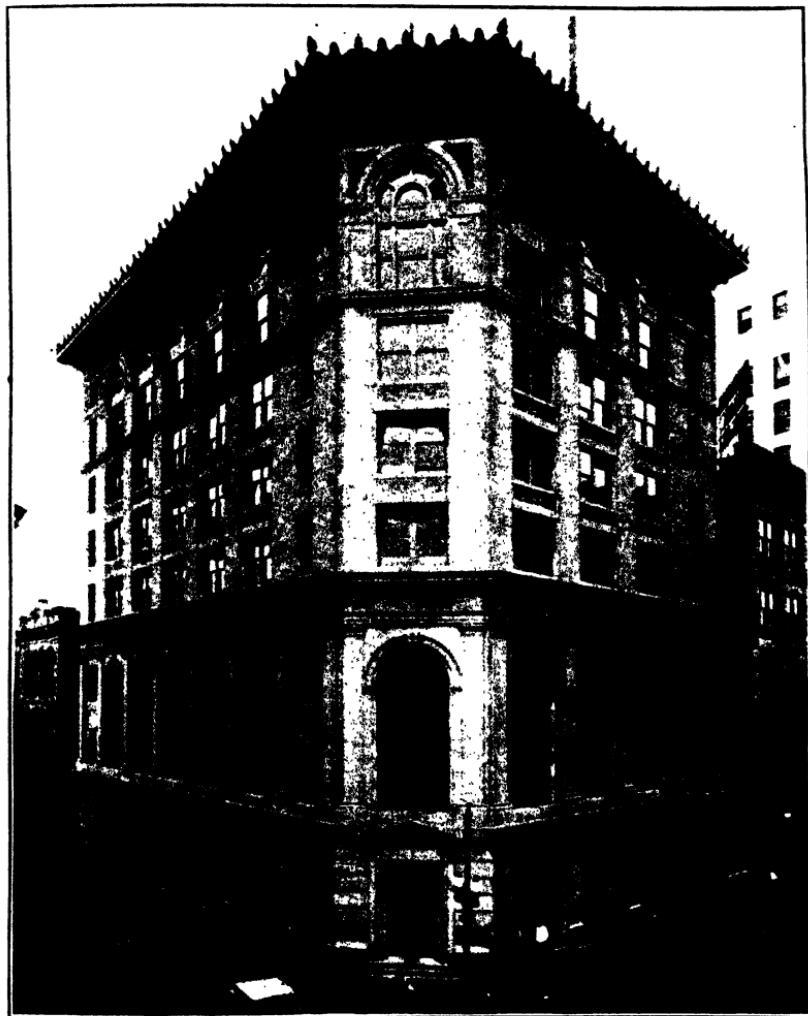


FIG. 116. - New Orleans Cotton Exchange Building. (Courtesy *H. G. Hester*.)

trouble of looking up men wanted became so burdensome that a number of the traders established the rule of meeting at a certain office at regular periods. It was soon realized that rules were needed by means of which the trading might be regulated. To

make and enforce rules required an organization. This led to the organization of the New York Cotton Exchange in 1870. It was incorporated the following year.

The purposes of the organization as expressed in its charter are:

The purposes of said corporation shall be to provide, regulate, and maintain a suitable building, room or rooms, for a Cotton Exchange, in the City of New York, to adjust controversies between its members, to establish just and equitable principles in the trade, to maintain uniformity in its rules, regulations, and usages, to adopt standards of classification, to acquire, preserve, and disseminate useful information connected with the cotton interests throughout all markets, to decrease the local risks attendant upon the business, and generally to promote the cotton trade of the city of New York, etc.

The membership in the New York Cotton Exchange is limited to 450 members. Applicants for membership must be over twenty-one years of age and of good character and financial standing. There is an initiation fee of \$1,000 and certain annual dues. Membership rights may be bought, either from a member or at auction in the exchange room. According to Hubbard,<sup>1</sup> in 1922 the value of a membership was about \$18,000. The membership includes many prominent cotton men, some living in parts of the country distant from New York City, cotton dealers, exporters, manufacturers, etc., who buy and sell both spot and future cotton. About 150 members, or their representatives, are on the floor of the Exchange daily transacting business.

The New York Cotton Exchange has as officers a president, a vice-president, a treasurer, and a board of fifteen directors. All of the officers are elected annually. The chief officer in active management is the secretary, who is paid a salary. He is the superintendent of the Exchange, collects and publishes statistics, manages the office, and acts as chairman when calls are made on the floor.

The New York Cotton Exchange is a corporation acting under a charter given by the state of New York, but in the trading in cotton the members act individually.

*Daily Routine on the Floor of the New York Exchange.*—At ten o'clock the superintendent of the Exchange appears on the rostrum at one side of the trading ring, rings a gong, and announces trading open for the current month. Then all traders wishing to buy or sell for that month make their offers. The

superintendent, acting as chairman, repeats the offers and announces sales, which are recorded on a blackboard at the opposite side of the ring (see Fig. 117). After the trading for the current month has stopped, the chairman announces the next month. Most of the trading is for March, May, July, October, December, and January. These are known as active months. After the trading for the second month has closed, another is announced, and so on around the year. After the round has been made, the chairman announces the "Call adjourned, Market



FIG. 117.—Trading ring, New Orleans Cotton Exchange. (Courtesy H. G. Hester.)

open." Trading is then carried on promiscuously around the ring by members, any month being dealt in. Offers and bids must be announced aloud and sales reported.

The quotations on sales are recorded on the blackboard. The pit, or spot where the traders stand, is surrounded by a ring of steps, three up and three down (see Fig. 117). Another call of months is made by the chairman at 11:45 and another at 2:45. On Saturday there is but one call. After the close of the Exchange at 3, no further trades are allowed.

The traders carry purchase and sale slips, on which they keep temporary record of their sales and purchases. These are later recorded in their offices. Final settlement is made in the clearing house.

*The New York Futures Contract.*—The New York futures contract is as follows:

New York, . . . . . 192 . . . . .  
of the County and State of New York, have this day  
{ sold to } . . . . . and agree to { deliver to }  
{ or bought from } . . . . . or receive from }  
of the same place, 50,000 pounds in about 100 square  
bales of cotton, growth of the United States, at the price of . . . . . cents per  
pound for Middling, with additions or deductions for other grades in accord-  
ance with the provisions of the United States Cotton Futures Act, Sec. 6,  
deliverable from licensed warehouses, in the Port of New York, between first  
and last days of . . . . . inclusive, the delivery within such time  
to be at the seller's option, in one warehouse, upon notice to the buyer, as  
provided by the By-laws and Rules of the New York Cotton Exchange.  
The cotton dealt with herein or delivered hereunder shall be of, or within,  
the grades for which standards are established by the Secretary of Agriculture,  
except cotton prohibited being delivered on a contract by the fifth  
subdivision of Sec. 5 of the United States Cotton Futures Act, and shall be of  
no other grade or grades, and shall be subject to the New York Cotton  
Exchange inspection.

Either party may call for a margin, as the variations of the market for  
like deliveries may warrant, which margin shall be kept good.

This contract is made in view of, and in all respects subject to, the  
regulations made pursuant to said United States Cotton Futures Act and to  
the By-laws and Rules of the New York Cotton Exchange not in conflict  
with the said Act or said regulations. Subject to the United States Cotton  
Futures Act, Sec. 5.

*How a Non-member May Trade on a Cotton Exchange.*—Some  
members of exchanges dealing in future contracts buy and sell  
for their own firm only. Others do a brokerage business in addi-  
tion to their own firm business. They will buy or sell futures for  
responsible parties living anywhere in the country. One hundred  
bales, or about 50,000 pounds, is the minimum amount that may  
be bought or sold. The brokerage charge, which varies some-  
what at different times, is about \$10 for buying or selling 100  
bales. In addition to paying the brokerage, the purchaser must  
make a deposit, for each 100 bales bought, of \$100 to \$500, which  
is known as a "margin." This sum is deposited with the clearing  
house or a trust company to guarantee the broker making the

purchase against loss due to market fluctuations. If the market is declining sharply, the broker may call for an additional margin. If this is not supplied, the broker may sell and close out the transaction. Brokers may buy for firms of known financial responsibility without requiring a deposit.

*Hedging.*—Hedging, as noted in Chap. XIX, is a sort of trade insurance which a cotton grower, merchant, or manufacturer may secure from a cotton exchange by selling or purchasing future contracts for cotton. It is defined by Hubbard<sup>1</sup> as follows: "Hedging is trade insurance carried on in such a manner as to make a world-wide market for instantaneous buying and selling." The use of hedging by a cotton grower may be illustrated as follows: We will suppose that a grower has 300 acres of cotton planted and in July it gives promise of a good yield. The future market for December is 25 cents a pound. At that price per pound the grower will make a fair profit in his business. Since his neighbor's crops are good and crop condition reports indicate good crops over a considerable part of the Cotton Belt, it looks as if the market price might be lower during October and November, when his cotton would be ready to go on the market. There is, of course, a possibility that there will be mishaps to the crop and that the price will be better than 25 cents a pound in the fall. It looks to the grower, however, that a price of 25 cents a pound with a sure profit is better than an uncertain one, even if there is a possibility of a better price. Consequently, he sells 100 bales of December futures at 25 cents a pound. If, when December comes, the market price is better than 25 cents a pound, he can sell his cotton on the market and buy futures to balance the ones he has sold, or to deliver on his contract. If the market price for spot cotton is much higher than 25 cents a pound, the future market will likely be higher than 25 cents also.

If the grower buys futures to deliver for those sold, he will lose on his future deals, but he has gained on the spot cotton. If the market has declined as he expected, he can deliver his spot cotton on the contract and realize 25 cents a pound less brokerage fees.

A manufacturer sells goods several months in advance and protects himself by buying future contracts for cotton to be delivered in the future when the goods are made. He bases the price of his goods on the price of the future cotton, so his profits are secure.

A cotton buyer or merchant protects himself continually against a fall in prices by selling future contracts to balance the spot cotton that he buys.

It occurs to the writer that cotton growers might profitably make more extensive use of hedging than they do. Probably many do not understand the benefits that may be obtained. Many others do not have control of enough cotton to make a future sale. But it seems that two or more might combine interests and make a sale.

**Delivery on a Future Contract.**—Theoretically, all the cotton that is sold on a future contract is to be delivered, but actually only a small percentage is delivered. The amount varies somewhat in different years the variation depending on market conditions. In the New York Exchange it is rarely more than 1 or 2 per cent of the amount sold, and is usually only a small fraction of 1 per cent. Deliveries may be stopped by ring settlements.

The cotton that is delivered is good cotton. It must have a staple length of  $\frac{7}{8}$  inch or more, be of a grade of Low Middling or better, and meet other government specifications mentioned in Chap. XIX. The bales delivered may vary in grade and staple; that is, they are not even-running. This makes them less desirable for the spinner, but does make delivery on contract easier. If a certain grade and staple length are specified, it may be difficult to procure the cotton in the market when wanted. The cotton delivered being of different grades, it is settled for on a Middling basis, the relative values being determined by an average of the values for various grades in the ten designated spot markets of the country which quote prices daily. New Orleans is a designated spot market, and uses prices of that particular market in settling future-contract business.

The cotton futures law now in force requires that the person or firm selling a future contract must give notice in writing of intention to deliver cotton on the future contract. This notice must be given 5 days before date of delivery. It is probable that the person to whom the contract was first sold has sold contracts himself and will transfer the notice of delivery to another. The notice may be transferred by several firms. The last to receive the notice within the time limit must either take the cotton or arrange some form of settlement.

**Preparation of Bales for Delivery.**—Prior to delivery, bales of cotton in a warehouse are inspected, weighed, sampled, and

classed. The classing is done by the government Board of Classers, and the inspecting, weighing, and sampling are done by exchange officials.

When the person delivering the cotton has received the classification certificates, these, with warehouse receipts, are turned over to the buyer and a check in payment of full amount of the bill is rendered in return.

**Value of Exchanges to the Cotton Industry.**—A great deal is said in favor of cotton exchanges, but, on the other hand, they are subject to much criticism. A considerable part of the criticism comes, however, from people who either do not understand their workings or fail to realize the benefits. Almost all well-informed men connected with the cotton industry and all marketing specialists have come to the conclusion that cotton exchanges, when operating under proper government regulation, are of assistance to the cotton trade. They broaden the market, stabilize prices, spread abroad information in regard to market values, and afford a good, convenient means of trade insurance.

Perhaps it will be well to quote from authorities who have made a careful study of the subject of cotton exchanges. Here is what the Committee on Agriculture on the Smith-Lever bill, Sixty-third Congress, Second Session, had to say in their report about the functions and economic uses of cotton exchanges:

It is the opinion of the committee that the abolition of cotton exchanges would result inevitably in the monopolizing of the entire cotton crop into the hands of a very few powerful interests, with the force and means to fix the price at which the farmer would be compelled to sell his cotton. Fully 75 per cent of American-produced cotton leaves the hands of the producer during the four months of September, October, November, and December. It takes no stretch of the imagination to foresee how utterly helpless the farmer, as a class, would be in his present disorganized condition as a factor in fixing the price of his own products, as against the organized genius and money of the spinners and powerful spot-cotton dealers. Any legislation, therefore, which eliminates from the cotton trade the element of a legitimate speculation and legitimate speculators must, in the opinion of the committee, result disastrously to the producers.

We have also a copy of a letter by W. B. Thompson, of New Orleans, recently read before the United States Senate when the Comer Amendment to the United States Futures Act was being considered. Mr. Thompson was formerly president of the Louisi-

ana division of the American Cotton Association, an extensive cotton grower, a cotton merchant, and at one time president of the New Orleans Cotton Exchange. He was thus in position to view the subject of cotton exchanges from various angles. He says in part:

In times past I have made a rather close study of the future contract, and I have long since come to the conclusion that its chief, and indeed its only, value lies in the protection it affords buyers and sellers of cotton and manufacturers of cotton goods. When the future-contract cotton functions normally, the owner of the cotton, pending such time as he can market the same, or, if he be a farmer, before he has made the same, can insure himself against loss by selling a future-contract hedge; the cotton buyer can make forward contracts with the spinner before he has any cotton in hand and protect himself against loss by buying a future-contract hedge; and the manufacturer may make forward contracts for the sale of his product before he has cotton in hand or a specific grade contract with the spot merchant or broker and insure himself against loss by buying a future-contract hedge.

It is the hedge, or price-insurance function of the future contract, which makes it valuable to the trade. It was never intended nor will it ever be possible to make the future contracts for cotton bought and sold around the rings of the exchanges take the place of direct dealings for specific grades and staples between the manufacturer and the spot merchant.

These contracts, which provide the protection aforesaid to those who do not want to speculate, are supplied primarily by those who want to speculate and whose business is to speculate. These latter are the underwriters, who assume the risk. From this postulate it is obvious, therefore, that the form of the contract or the character and the extent of the obligation to which the speculative seller or buyer is called upon to commit himself becomes the determining factor in the existence of a future-contract market. If the contract is too narrow or if it contains conditions which place the seller at a disadvantage, then there will always be more buyers than sellers, and, in consequence, the contract will go to an artificial premium, and if these disadvantages are exaggerated, the price of contracts, irrespective of the value of cotton, will go through the roof, and you will no longer have any contract market, because nobody will be willing to take the short side of the contract. If, on the other hand, the contract be too broad and the advantages all be with the seller, buyers will be driven from the market, and the whole system of the future trading will be destroyed.

In order, therefore, that supply of contracts may be forthcoming and a future-contract market possible, it is necessary that the authorized contract shall be one to which both the speculative buyer and seller

will be willing to commit himself. It must be a basic contract, because no speculative seller of future contracts would commit himself to an obligation to deliver a specific grade which it might be impossible for him to obtain, and the range of deliverable grades should be sufficiently wide to give him a reasonable assurance that he could secure the cotton necessary to liquidate his contract should he be called upon to do so. On the other hand, the buyer must have assurance that he will not be called upon to take delivery of unmarketable cotton or of any cotton at artificial price differences.

I am very much in favor of the future-contract market properly regulated. In fact, it is my opinion that it would be a great calamity to the producer if the future markets were destroyed or impaired.

The following extract from a letter written by Henry Wallace, Secretary of Agriculture, to the Chairman of the Committee on Agriculture in the House of Representatives, gives his views on limiting future trading. After mentioning the fact that the House committee had at different times thoroughly investigated the subject of cotton futures, he says:

In each case, as we understand it, the committee reached the conclusion that, while the regulation of the future exchanges in some form was desirable, it was not prepared to recommend even a limitation upon speculative trading.

**Objections to Exchanges.**—Criticism is often made against exchanges to the effect that the members manipulate buying or selling in such a way as to cause a rise or fall in the markets as suits their financial interests. It is true that a number who are interested in seeing the price advance, "bulls" they are called, can act together in buying and cause some immediate change in prices, but the movement will be of short duration unless there is some real market condition to back it up, as very adverse weather conditions, unusual demand for cotton, or something of the sort. Some of the members of the exchange are always interested in seeing the price of cotton fall, "bears" so called, who will rally and struggle against the advances fostered by the "bulls."

Two attempts at "corners," that is, attempts to buy up all available cotton that could be delivered on contract at a certain market at a certain time, have been made by New York firms and others since 1900. These "corners" make available cotton so scarce that those who have sold future contracts may pay extreme prices for the cotton to deliver on their contracts when they come due.

Engineering a "corner" requires much capital and is attended by a large financial risk. Much cotton must be bought at a high price as the market advances. A part of this must be sold later at a lower price on a declining market. It is questionable whether either of the "corners" mentioned was a success financially. In the second "corner" in 1910, the leaders were indicted and fined for violation of the Sherman Anti-Trust Act. The government charged that there was an agreement between the parties concerned which resulted in restraint of trade.

During the period of high prices incident to a "corner" the growers, merchants, or anyone who has cotton to sell may profit by the high prices, but usually the "corner" is engineered at a time when there is a scarcity of cotton, and after it has passed out of the hands of the growers and primary buyers. The high prices are artificial in a sense, and are not just. All that one party gains someone else loses. "Corners" are illegal. It is the intent of rules adopted by exchanges and of our federal laws to prevent them.

**Effect of Closing the Future Exchanges.**—During the summer of 1914, the future exchanges of the country were closed for 3 months. Extreme market fluctuations due to the outbreak of the World War and the failure of firms dealing on the future market made this action necessary. While the exchanges were closed cotton trading was largely at a standstill. There was no definite world market. Prices differed in different towns, the variation depending on the sales in sight. Merchants could not safely buy cotton, because they could not hedge to secure themselves. The same was true of manufacturers. It was not long after the exchanges had been closed until there were calls for them to reopen. Since that time there have been fewer demands for the abolition of future exchanges than previously. It was clearly shown that they have a legitimate function.

**Legislation to Control Exchanges.**—As was stated previously, there has been a clamor for the abolition of future exchanges, or the adoption of such stringent control measures that trading on them would be hindered. A number of bills dealing with the matter have been introduced in Congress. When the bills were up for consideration, the Senate and House committees gave public hearings, inviting in prominent men in various branches of the cotton industry. They made an earnest effort to secure all possible information from all interests.

The United States Cotton Futures Act was passed in 1914, but was later declared unconstitutional. It was reenacted, with certain changes, in 1916 and amended in 1919. Some of the principal provisions of the law as it now stands are:

1. The cotton bales traded in shall be considered as weighing 500 pounds.
2. Middling shall be the basic grade unless some other is specified in the contract.
3. The cotton delivered shall be of the grades for which official standards have been prepared.
4. The relative value of different grades shall be determined by commercial differences existing in the ten designated spot markets.
5. Cotton shall not be delivered if the grade is below Low Middling; or, if tinged, below the grade of Strict Middling; or, if yellow-stained, below the grade of Good Middling; or if the staple is less than  $\frac{1}{8}$  inch in length; or if of perished staple, gin-cut staple, reginned staple, or immature staple; or if the cotton is repacked, false-packed, mixed-packed, or water-packed.
6. Notice of intended delivery must be given on the fifth business day prior to the date of delivery.
7. When the cotton is tendered, there must accompany each tender a written statement of each and every bale by tag number, showing the grade.
8. All cotton tendered shall be classed by government classers.
9. A tax of 2 cents a pound shall be levied on cotton sold for future delivery if the provisions of the act are not obeyed.

In addition to the federal laws for the control of cotton exchanges, each exchange has a number of restrictive rules of its own. Some of these, as, for instance, the one limiting market fluctuations to 200 points for any one day, have been adopted at the suggestion of government authorities.

**Speculation in Cotton.**—The buying or selling of cotton futures with the sole idea of making money by a rise or fall of the market price is termed speculation or gambling in cotton. Speculation is defined in Webster's International Dictionary as:

Engaging in business out of the ordinary, or by dealing with a view of making a profit from conjectural fluctuations in the price rather than from earnings or the ordinary profit of trade, or by entering into a business venture involving unusual risks for a chance of an unusually large gain or profit.

Speculation, while confined within moderate limits, is the agent for equalizing supply and demand and rendering the fluctuations of price less sudden and abrupt than they would otherwise be.

There is speculation in futures, in spot cotton, and in various other commodities. A merchant who buys spot cotton and holds it for a higher price is speculating in a sense. He is taking a chance on making a profit by a rise in price. While speculation is harmful to the public in some ways—has a tendency to create artificial or unnatural market conditions—it is not without value.

As was brought out in the second paragraph of the definition quoted above, it assists in equalizing supply and demand and in reducing price fluctuations.

Many of the sales and purchases made on future exchanges are for the purpose of hedging and are considered legitimate trading. Hubbard<sup>1</sup> says that, when a careful survey was made of the New York Exchange when it closed in 1914, it was found that 85 per cent of the business was for hedging. A few years later, President Marsh estimated that 75 per cent of the business then being carried on was for hedging.

**Market Statistics.**—A trader on a future exchange, to be successful, must be wide-awake, do much thinking, and make a careful study of crop statistics. To assist the trader, the exchange collects and posts or publishes all available data on crop conditions in all parts of the world: weather conditions, insect depredations, cotton ginned, exported, stored in warehouses, consumed, etc.

#### References

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3. HAMMOND, M. B.: "The Cotton Industry," American Economic Association, New York, 1897.
4. Anonymous: "Cotton Futures." A Compilation of Certain Public Documents Dealing with the Enactment, Amendment, and Administration of the Act to Regulate Trading in Cotton for Future Delivery, Government Printing Office, Washington, D. C., 1922.

## CHAPTER XXI

### ECONOMICS OF COTTON PRODUCTION

Conditions obtaining in the American Cotton Belt, both natural and man-made, are very favorable for the production of cotton. In fact, it is doubtful if there is in the world any other territory of such wide expanse so well suited. As has been seen elsewhere in this work, the climate is exceptionally favorable; the summers are warm and long; the rainfall is rather plentiful during the spring and early summer months, when the young cotton plants need rain for good growth, but scanty during the fall, when dry weather is desirable for picking and for the protection of the open cotton bolls. The soil is naturally rich. Where it has been run down by continuous cropping, it may be made productive again by the use of proper fertilizers. The labor supply is fairly plentiful. The cotton fields are not far removed from cotton mills and consuming markets. Numerous good roads and adequate railroad facilities make transportation easy.

**Foreign Competition.**—For a good many years, the United States has had virtually a monopoly of the cotton market, due to the fact that it produced one-half to two-thirds of the cotton supply of the world. But this monopoly cannot be maintained unless the country produces cotton economically, so that it may be sold at a moderate price and yet yield profit to the producer. If it is not sold at a moderate price, foreign nations will be stimulated to activity in growing cotton. During the period of high prices from 1860 to 1870, England and some other European countries made special efforts to foster cotton growing in their colonies. More recently during the period of high prices incident to the World War, renewed interest was taken in cotton growing in several countries where cotton has not been grown extensively.

There are large areas of fertile land suited to the growing of cotton in the Sudan region, and in the Congo district of Africa; in Brazil and Argentine in South America; in Mexico; and in other parts of the world. The land in much of these regions is very well suited to cotton, and the climate, while probably not so well adapted as that of the American Cotton Belt, does serve

very well. The main hindrances to the industry in these new territories are lack of labor and in adequate means of transportation. But if prices are high enough to make the growing of cotton very profitable, unemployed labor in Europe will probably be drawn to the regions; and if there is a chance for good profit on the investment, capital for building railroads and securing other means of conveyance will not be hard to obtain. If large quantities of cotton are produced in other countries, America cannot produce her usual amount without there being an overproduction. Overproduction brings a glut on the market and reduced prices.

**Cost of Cotton Production.**—A good many estimates of the cost of cotton production have been issued. These show a wide variation in opinion. The variation is largely due to different ideas in respect to the size of the wage the laborers should receive and in respect to whether or not all the time of laborers and mules should be charged to the cotton crop. Some, of course, express opinions which are mere impressions, and are not based on facts.

Some estimators fail to consider that the cotton field laborers should have the opportunity of living in some degree of comfort, and have some educational advantages. During slavery days and for a good many years afterwards, they lived largely in squalid cabins and had very limited rations. Under such conditions cotton could be produced at a low cost. Plantation owners figured that they could make money even if the cotton did not sell for more than 8 or 10 cents a pound. With impressions gained from viewing such conditions, some have come to feel that nothing more is needed by the laborers and that cotton can be produced very cheaply.

Figures expressing the cost of cotton production at any particular time may not be applicable to other times because of fluctuating values in the purchasing power of money. For some decades prior to 1914 a dollar would buy almost twice as much as it will buy at present. Costs are best expressed in terms of hours of man and mule labor necessary for production, but even this will vary considerably in different regions, the amount depending on the productivity of the soil, the prevalence of troublesome weeds, insect pests, etc. If the date at which certain particular prices prevail is given, it assists in estimating values.

In figuring the cost of cotton production, some authorities consider only the hours of man and mule labor actually spent in plowing, hoeing, picking, etc., and allow the workmen a moderate wage for that time. This is not quite fair or right, because there

are overhead expenses, such as manager's salary, taxes, interest on money invested in machinery, in mules, etc. Mules and laborers must be fed the whole year in order that they may be available during the months when needed in the cotton fields. It does not seem that *all* the expense of support for the year should be charged to the cotton crop alone. A large part if it should be so charged, because, if the cotton crop has the first call for labor at all times, no great amount of other profitable or productive work can be done on the farm. To be sure, it should be the effort of the management to keep all labor employed at all times, but during the winter and during periods of rainy weather at other times in the year this is not always possible. Consequently, the income from the cotton crop must be drawn upon for support during this off season.

Other authorities are inclined to charge the entire expense for the year to the cotton crop, even if no special attempt is made to find other employment for laborers during the spare time. Man labor is estimated a regular monthly wage, at a fairly high figure, throughout the year. Extra labor hired for hoeing and picking is also allowed a comparatively high wage. This, it occurs to the writer, is going to the extreme in the other direction and is not fair. In so far as is possible, the work on the farm should be so organized as to keep man and mule labor employed continually during good weather, and so that soil fertility will be maintained. Overhead expenses should be prorated between the different incomes according to receipts. The proportionate for cotton plus the cost per acre of the actual labor, rent, fertilizers, seed, etc., will give the real cost of cotton production per acre. This total divided by the pounds produced will give the cost of production per pound.

*Low Estimates on the Cost of Production.*—Hammond<sup>1</sup> reports that, about 1840, certain American planters became alarmed lest India should become a rival in the production of cotton. They held a meeting to consider measures to counteract the work of the East India Company. After a lengthy discussion they decided that so long as the American planters could get 8 cents a pound for their cotton, delivered at the nearest market, they could afford to produce it. In 1849, several of the large planters of the Mississippi bottoms estimated that they could grow cotton for 6 cents a pound. In 1893, the Senate Committee on Agriculture and Forestry made a report to Congress on the condition of the cotton growers in the United States. This committee stated:

It is the general consensus of opinion that cotton cannot, except under the most favorable circumstances, be raised profitably at less than 8 cents a pound, nor without loss under 7 cents.

During most of the time since 1850 cotton has been worth 10 cents a pound or more on the New York market. Up to the World War period a price of 10 cents a pound was considered sufficient to pay cost of production and marketing expenses, and perhaps to yield the producer a small margin of profit.

*High Estimates on the Cost of Cotton Production.*—The following estimate of the cost of producing the 1920 cotton crop was made by a prominent member of the American Cotton Association. This estimate was made during a period of very high prices. It will be noticed that the estimator charged the cotton crop with wages for a man for an entire year and likewise the rent and feed for a mule. Under usual conditions labor costs per day are not more than one-half the sum given in this estimate. The estimator says:

The figures used below are based upon a 20-acre cotton farm. It will take all the time of one laborer and one plow animal to do the plowing required in cultivating such a farm and the outside work necessary to its general upkeep. While more can be cultivated in some parts of Texas and Oklahoma, less can be cultivated in a good part of the belt east of the Mississippi River. Twenty acres seems, therefore, a fair average. The estimate is based upon 160 pounds of lint per acre, that being about the average for the last 5 years.

ESTIMATE OF COST OF COTTON CROP, 1920

ITEM		
1. Rent 20 acres of land at \$10 per acre.....	\$ 200.00	
2. Rent one plow animal, 1 year.....	65.00	
3. Feed one plow animal, 1 year.....	282.00	
4. Ginning 9,600 pound seed cotton at 30 cents per hundred.....	28.80	
5. Deterioration of farm implements.....	20.00	
6. Labor, one man one year, at \$80 per month.....	960.00	
7. Extra labor, hoeing over crop three times, 75 days, at \$2.75 per day.....	206.25	
8. Picking 9,600 pounds seed cotton, at \$2 per hundred.....	192.00	
9. Fertilizers.....	33.00	
10. Planting seed.....	10.00	
Gross expense.....	\$1,997.05	
Less 3 1/2 tons seed at \$60 per ton.....	192.00	
Net expense.....	\$1,805.05	

20 acres at 160 pound per acre will yield 3,200 pounds lint.

$\$1,805.05 \div 3,200 = 56.47$ , or 56.47 cents, the cost of producing a pound of lint.

*Estimates by U. S. Department of Agriculture Investigators.*—Several research men connected with the U. S. Department of Agriculture have made studies on the cost of producing cotton. In 1918, Moorehouse and Cooper<sup>2</sup> obtained records of labor and material requirements for 842 crops grown in ten different counties in four southern states. The laborers were allowed a fair wage and charges were made for overhead expenses, but no allowance was made for time that the labor was not actually employed in the crop. The range in cost was from 8 cents to \$1.07 per pound, but most of the cotton was produced at 28 cents a pound or less. The average cost was 23 cents.

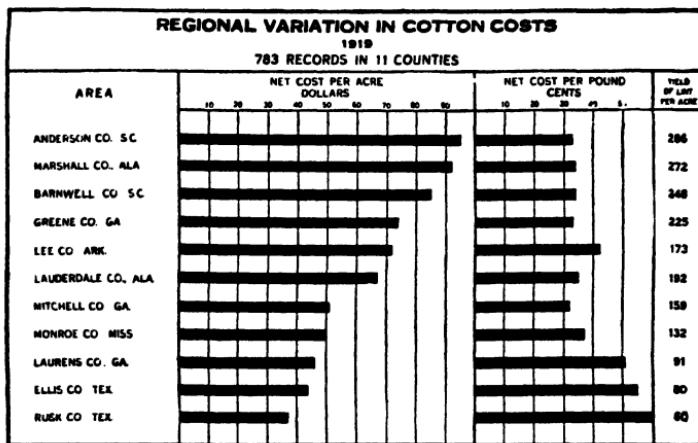


FIG. 118.—Variations both in the cost per acre and in the yield per acre cause variations in the net cost per pound of lint. The average acre in Anderson County cultivated at the highest cost in 1919 produced the highest average yield at the lowest cost per pound. (After Agelasto and others.)

Moorehouse and Cooper,<sup>2</sup> in 1919, obtained additional cost records from 821 crops grown in twelve counties in six different southern states. The bases used were very similar to those used in 1918. Table XL, lists the counties and states in which data were collected and gives the main results of the survey. These results are expressed in terms of material and labor requirements and not, with the exception of ginning charges, in dollars and cents. An effort was made to express the costs in a form that would be permanent, that is, usable any year and independent of fluctuating values. By considering prices paid for seed, labor, fertilizer, etc., during any particular year, this table may be used in determining the cost of production that year.



TABLE XII.—COST OF PRODUCTION BY YIELD GROUPS, 1923

Yield, pounds of lint per acre	Acres in rot- per farm	Yield per acre, pounds of lint	Pre- pare and plant	Gross cost per acre					Net cost of lint			Value of lint						
				Cultiv- ate	Har- vest	Ferti- lizer and man- ure	Seed	Dust- ing	Land rent	Mis- cel- laneous cost <sup>a</sup>	Total	Per acre (cot- ton seed)						
20 and under	32	55	14	\$3.69	\$5.25	\$2.11	\$0.70	\$2.94	\$1.14	\$0.22	\$3.52	\$1.52	\$21.00	\$0.74	\$20.35	\$1.45	\$ 4.28	\$0.30
21-60 .....	249	69	44	3.64	5.24	3.98	0.79	4.25	1.25	0.50	4.33	2.60	26.06	2.10	24.86	0.56	13.32	0.30
31-100 .....	451	55	89	3.91	5.73	5.57	0.79	3.97	1.16	1.33	4.88	2.57	29.91	3.60	26.31	0.30	26.55	0.30
101-140 .....	407	54	124	4.25	6.12	6.69	1.03	3.39	1.24	1.76	4.98	3.06	32.52	5.13	27.39	0.22	36.48	0.30
141-180 .....	394	70	161	4.18	5.92	7.60	1.11	3.55	1.22	1.99	5.09	2.74	34.30	6.79	27.51	0.17	47.73	0.30
181-220 .....	279	51	200	4.37	6.20	8.74	1.36	4.48	1.18	2.23	6.90	3.31	38.77	7.64	31.13	0.16	60.29	0.30
221-260 .....	257	63	245	4.71	6.59	9.85	1.56	5.04	1.40	2.77	7.08	3.33	42.33	9.71	32.62	0.13	72.60	0.30
261-300 .....	165	30	290	5.01	7.08	11.13	1.64	6.27	1.54	3.08	8.05	3.44	47.24	11.00	36.24	0.12	87.77	0.30
301-340 .....	34	56	324	5.26	8.51	13.39	2.46	9.03	1.64	3.32	9.59	5.00	58.29	12.64	45.65	0.14	95.34	0.30
341-380 .....	54	33	356	5.50	7.18	12.13	2.83	8.75	1.48	3.90	9.53	4.10	55.40	12.62	42.78	0.12	107.14	0.31
381-420 .....	94	31	401	5.71	8.62	13.74	2.37	10.41	1.51	3.71	8.91	4.37	59.35	14.98	44.37	0.11	124.22	0.31
421-460 .....	27	31	444	5.82	8.14	14.87	2.91	9.99	1.50	4.46	12.42	4.56	64.76	14.53	50.23	0.11	132.63	0.31
461-500 .....	60	26	495	6.09	7.75	17.71	3.04	9.73	1.55	5.17	10.43	5.54	67.01	17.94	49.07	0.10	150.42	0.30
501 and over	16	27	618	6.34	7.51	28.28	2.79	13.86	1.44	6.92	10.79	5.07	83.00	26.17	56.83	0.09	197.45	0.32

<sup>a</sup> Includes miscellaneous labor, irrigating and water, dusting and dusting material.<sup>b</sup> Includes picking sacks and sheets, crop insurance, use of implements, use of storage buildings, and overhead.

In a study of Table XI, it will be observed that the man-labor requirements are low in Ellis and Rush counties, Texas, and relatively low in Laurens County, Georgia. Comparatively low yields were obtained in these regions. The man-labor requirements in Washington County, Mississippi, and in Lee County, Arkansas, are especially high because much hoeing was necessary to keep down grass and weeds. Heavy applications of fertilizer were made in South Carolina and little or none in Mississippi, Arkansas, and Texas. It is apparent that the yields increase greatly with an increase in the use of fertilizers.

As has been mentioned elsewhere, the cost of producing cotton varies greatly in different regions, and during different seasons in the same region. Much depends on the natural productiveness of the soil, the weather, the fertilizers used, and other factors. Figure 118 shows in graphic form regional variation in cost per acre and cost per pound for the year 1919.

In 1923, Cooper and Hawley<sup>4</sup> collected data on the cost of cotton production from 2,519 farmers living in various parts of the Cotton Belt. At that time the price of labor and supplies had fallen from war-time levels, but was still considerably above prewar figures. The main results of their investigations are shown in Table XLI. In discussing their results, the authors say:

Cotton reports were received from 2,519 farmers, but the greater number were growers having yields considerably above the average. For this reason the costs are shown by yield groups, rather than by average costs by states and by the entire Cotton Belt.

The average yield of lint cotton in the United States in 1923 was 130.6 pounds per acre, according to the Division of Crop and Livestock Estimates, U. S. Department of Agriculture. Of the 2,519 reports received regarding the cost of producing cotton, 407 showed yields of 101 to 140 pounds per acre, averaging 124 pounds. This group appears most nearly to represent general conditions in the cotton states during 1925; the average net cost of production on these 407 farms was 22 cents per pound of lint, and the average price received was 30 cents.

Fifty-five per cent of all farmers reporting had yields of more than 140 pounds per acre and, on an average, produced their cotton at considerably less cost per pound than did those who had yields of 101 to 140 pounds of lint per acre.

Seven hundred and thirty-two, or 29 per cent, of the farmers reporting produced 100 pounds of lint or less per acre. Of these, 281 produced at a cost above the price received.

**Financial Condition of Cotton Farmers.**—Much has been said and written about the financial status of the cotton growers in the South. For several years after the Civil War conditions were indeed bad. The farms were run down, tools and equipment were scarce or lacking altogether, and there was practically nothing upon which to obtain loans. Even so late as 1893, J. Washington Watts, of Laurens, S. C., writing for a United States Senate committee report (Hammond<sup>1</sup>) said:

The actual financial and material condition of the cotton raisers is very bad; generally in debt. In my opinion, the majority are making their crop with supplies bought on credit, and are in debt to that extent at least. I estimate the proportion of insolvent to be at least three-fourths of our farmers. Those who raise even a portion of their supplies are doing fairly well, but very few do this, preferring to risk the cotton, which sinks them deeper in debt each year.

It is true even yet that many tenants are insolvent, or become insolvent in bad crop years, but the condition of the landholders is becoming better apparently. According to United States Census reports, in 1890 the farms in the ten leading cotton-growing states were mortgaged to 44.1 per cent of their value; in 1910 to 26.6 per cent of their value; and in 1920, to 29.2 per cent. The mortgages on farms in the whole United States held about the same ratio to the farm values as in the south: 35.5 per cent in 1890, 27 per cent in 1910, and 29.1 per cent in 1920. The total indebtedness on farms in the United States, expressed in dollars, was about four times as great in 1920 as in 1890. In the southern states the increase was even greater, ranging from about six times for Louisiana to twenty-seven times for Texas. The increase in property values more than kept pace with the increase in indebtedness.

**Financing Cotton Growers.**—Most of the share-croppers, renters, and small farmers who grow cotton require financial aid while working in their crop. With the share-croppers, the aid is usually furnished by the landowner, who charges about 10 per cent for the use of his money. The renters may likewise be furnished money by the landowner or they may open an account with a local merchant, who agrees to sell them, on credit, food, feed, and other supplies needed while growing the crop. Since the goods are sold on time and frequently to people who have little regard for their obligations, the time prices charged

are considerably higher than the cash prices. The merchant is given the right to buy the cotton grown, and can, of course, collect on the account if sufficient cotton is made. It sometimes happens that, if crop prospects look unfavorable during the summer or fall, the borrower runs away and leaves his crop. The loss occasioned by his departure must be made up by the more honest ones who remain. Consequently, time prices are high, unreasonably high in many instances. The poor, plodding farmer may get in debt to the merchant, and, if his family does not practice strict economy, may find it almost impossible to get out again. Hammond,<sup>1</sup> writing in 1897, said:

The use of the credit system is not confined to a small number of the farmers of the Cotton Belt. Ninety per cent of the cotton growers of Alabama, it is stated on high authority, make their purchases in this way, and pay prices on an average 25 per cent higher than do their neighbors who buy for cash. Throughout the Cotton Belt it is probably no exaggeration to say that three-fourths of the cotton planters and their tenants, white and black, buy on time, and pay usury to factors, merchants, or others who have advanced money or supplies on the prospective cotton crops of the borrowers.

While the percentage of cotton growers who buy on time from local merchants is not so large as it was in 1897, there are still a good many. An increasingly large number borrow money from banks or other money-lending concerns and then pay cash for their supplies.

According to studies made by the U. S. Department of Agriculture<sup>3</sup> in 1921, the average prevailing rate of interest charged farmers in the leading cotton-growing states on personal and collateral loans was:

	PER CENT		PER CENT
North Carolina.....	6.23	Alabama.....	8.46
Tennessee.....	7.88	Georgia.....	8.94
South Carolina.....	8.06	Texas.....	9.68
Mississippi.....	8.11	Oklahoma.....	9.84
Louisiana.....	8.34	Arkansas.....	9.70

The actual charges were somewhat higher than the foregoing figures indicate, as the interest was usually collected in advance and in some cases the borrower was required to maintain a deposit at the bank.

Table XLII from Agelasto<sup>3</sup> furnishes data on the forms of security given banks by cotton farmers.

TABLE XLII.—FORM OF SECURITY GIVEN FOR PERSONAL AND COLLATERAL BANK LOANS TO FARMERS IN TEN LEADING COTTON STATES; PER CENT OF LOANS SECURED BY VARIOUS FORMS OF SECURITY

State	Note without indorsement	Note with one or more indorsements	Mortgage on live-stock	Crop lien	Warehouse receipt	Stocks and bonds	Other ways
North Carolina	10.5	68.6	1.7	5.2	2.1	7.5	4.4
South Carolina	9.1	41.0	13.6	20.2	9.7	4.8	1.6
Georgia.....	12.5	50.1	14.5	4.9	10.0	3.5	4.5
Tennessee.....	18.1	67.2	5.0	1.5	0.8	5.8	1.6
Alabama.....	10.4	20.1	31.5	26.1	7.5	2.4	2.0
Mississippi.....	12.7	27.0	20.2	15.1	8.0	9.1	7.9
Arkansas.....	12.1	37.9	22.7	19.9	3.0	2.2	2.2
Louisiana.....	15.5	52.7	12.4	5.2	2.7	9.0	2.5
Oklahoma.....	17.2	12.5	49.3	18.1	0.7	1.2	0.6
Texas.....	21.9	18.0	38.1	18.3	1.6	1.1	0.0

Recently certain cotton cooperative marketing associations have been able to borrow large sums of money for use in making advances on cotton and for other expenses. By joining together, the members of the association need no outside financial backing, and are able to get plenty of money at a low rate of interest.

**One-crop System.**—A one-crop system of farming is followed on a large number of the farms of the Cotton Belt. It may be inquired why this is so. There are several factors influencing or having a bearing on the matter. Growing cotton in the South is a well-established custom. The labor knows how to grow it and the farm owners and managers feel that they can superintend a cotton farm better than any other. To change a custom requires considerable effort. Cotton can be grown and harvested with the use of but very little machinery. The less machinery the average colored laborer has to use the better he gets along. The negroes like to grow cotton because they are used to it and because they can work together in the fields in groups much of the time, especially while hoeing and picking. They talk, joke, and sing, and have a good time socially. Cotton in the form of bales keeps indefinitely without deterioration if kept dry. It is easily marketed.

Probably the chief reason for growing cotton largely to the exclusion of other crops is to be found in the belief of the land-owners that cotton will pay better than any other crop. This is probably true if the practice is not carried to the extreme in growing too much. But many growers do go to the extreme, and neglect to grow supplies needed for home consumption. They see an acre of cotton and have visions of a bale to the acre and the bale selling for a large sum, say \$100. They compare the returns from an acre of corn with the visionary returns from the acre of cotton. The acre of corn is not apt to yield more than 25 bushels, which at \$1 a bushel will bring but \$25. The cotton looks to be a far better crop. But there are several things that the grower fails to consider. First, the yield is apt to be much less than a bale. The average yield is not more than one-third of a bale, and less than that may be made. The price is very apt to be low if a good crop is made. As a rule, the price is nearer 10 than 20 cents. A third of a bale at 10 cents a pound does not make a very large sum, only \$16.66. Cotton is an expensive crop to produce in that it requires much hand labor. The landowner will have to give at least half of the cotton produced to pay for the man labor used in making the crop. This leaves him but \$8.33 for his acre of cotton. With this sum he must pay for feed for his work animals for a year; feed bought at a high price if it has to be shipped in from a distance; buy harness, plows, seed, and fertilizer, pay taxes, provide for the upkeep on houses and buildings, and meet losses sustained when croppers, who have been "furnished," or given their supplies, for making the crop, fail to make enough to pay their debts.

But this is not all. The one-crop cotton farmer is continually using up the fertility of his soil. The land is becoming poorer and poorer. In a corn crop may be grown soybeans or cowpeas, which will improve the soil and also yield a fair money return in hay or seed. Sudan grass, sweet potatoes, peanuts, sorghum, sugar cane for syrup, and oats are other crops that may be grown to advantage on a cotton farm. In many instances cotton growers who have attempted to diversify or grow other crops in addition to their cotton, have failed because no market was provided in advance for the product and the labor was inexperienced in handling the new crop.

There is considerable business hazard in the one-crop system of cotton farming. If the crop is a failure, there is sure to be con-

siderable loss, because there is not only the loss of the rent on the land but the labor and work animals have to be supported a whole year to make one crop. In most instances, the labor is furnished with supplies without any security. If the yield is very large, there is danger of overproduction and a low price; yet it costs much to harvest a large crop.

The family of the one-crop farmer usually suffers from lack of good food. If it all has to be bought at the store at a high price, the variety is not apt to be great or satisfactory; fruits and fresh vegetables may be lacking altogether.

Also the one-crop system is not economical, as it does not provide sufficient employment for the labor and work animals. In a survey made by Willard<sup>5</sup> in Ellis County, Texas, in 1914, it was found that on small farms the mules worked at productive labor but 60.3 days during the year. On the larger farms they worked 79.1 days. The men on the all-cotton farms do not work in the fields more than half the working days of the year, and the women and children not more than one-third.

**Share-crop System.**—A large part of the cotton grown in the United States is grown by share-croppers, persons who furnish the labor, or labor and teams, and receive in return a stated portion of the crop grown. Although this system is frequently criticized adversely, it is the opinion of the writer that it is better than a wage system. The tenant takes more interest in the crop than he would take if he were working for wages, and he requires less supervision. The negro laborer likes the system, because he is his own boss to some extent, and he has a chance to make more money than he would have if he were working by the day for wages. He is usually given rations or supplies by the landowner. He is thus guaranteed a living whether he makes anything or not, and has a chance to live off the future crop.

**Growth of Tenancy.**—Figures obtained from the U. S. Census Bureau show that tenancy is increasing. This does not mean necessarily that the landowners are losing their farms and becoming tenants, but that the proportion of tenant farmers is becoming greater. This is probably due, in part at least, to the fact that with the increase in value of lands and the increase in population, it is becoming more and more difficult for men who do not have land to obtain it. Consequently, more of them, if they become farmers, rent land to farm.

The increase of tenancy is viewed with some degree of displeasure by the public, because tenants move from place to place and cannot be expected to take as much interest in building up the community as do the more permanent residents. A hopeful sign is to be seen, however, in the working out, and adoption in some sections, of long-time leases. These are of mutual advantage and make the tenant a more permanent citizen. With the usual short time lease under which land is usually rented, the tenant takes no interest in improving the land or building up the property. He feels that it is to his interest to get as much out of the place as he can during the short time he has it and to spend as little as possible in improvements. As a result, the farms that are rented deteriorate rapidly to the loss of both owner and the renters.

**Overproduction.**—It frequently happens that more cotton is produced than can be marketed advantageously. This results in what is termed "overproduction." It does not mean necessarily that the world does not need the cotton, but that conditions are such that it cannot be marketed, satisfactorily, and low prices prevail. The period from 1891 to 1895 was a period of low prices, the average value of lint cotton being 7.81 cents. Hammond and others attribute these low prices to overproduction. About that time extensive new areas were opened west of the Mississippi River, especially in Texas. During the season of 1914 a fairly large crop was produced. World War hostilities so interfered with the exporting and marketing of this crop that cotton became a glut on the market and there was apparently great overproduction. High prices for a year or two may stimulate cotton growing and result in the production of more cotton than can be sold at a good price. The one-crop system in vogue in much of the South is probably a contributory factor to overproduction. There is no other crop to which the farmers are prepared to turn, or which they know how to grow successfully. They are forced into a goodly cotton acreage, although the outlook is not bright and they feel that they should reduce acreage. The credit system in use in many parts of the Cotton Belt is another contributory factor to frequent overproduction. Credit merchants and banks have usually considered a cotton crop better security than any other the farmer could plant, and have, consequently, encouraged him to plant more and more cotton.

The production of more cotton than can be marketed advantageously is, of course, not sound business practice and may result in considerable financial loss to the grower. As a rule, when there is prospect of overproduction the following year, considerable effort is made by newspapers, the extension force of the U. S. Department of Agriculture, chambers of commerce, and by other public-spirited organizations and individuals to persuade the farmers to curtail their acreage. Their efforts may have some effect, especially on the farmers that are in position to diversify their crops.

**Lack of Economy in the Cotton Belt.**—Many families living on farms in the Cotton Belt have little or no garden, although with slight effort they might have an abundance of fresh vegetables nearly the whole year. An orchard is a rarity, yet peaches, grapes, figs, plums, blackberries, and some other fruits can be grown in abundance. It is the practice of many of the tenant farmers to spend money freely if they have it and to use poor management in planning their business.

**Efficiency in Farm Management.**—Experience on cotton farms the last few years has demonstrated that it is best to provide for growing needed home supplies first, and then plant the rest of the land in cotton. The most successful farmers are the ones who grow the feed needed for animals on the farm, who keep plenty of cows, pigs, and hens, and who grow corn, potatoes, cowpeas, and garden vegetables. Such farmers have well-fed families, and although only a moderate amount of cotton is grown, the money it brings in clear money—it need not be paid out for supplies.

On a well-organized farm where diversification is practiced, living conditions are better than on a one-crop farm, expenses may be kept down to a minimum, labor and work animals may be employed a large part of the time on the different crops, and the productiveness of the soil may be maintained. Where all-cotton farming is practiced, the soil is sure to decrease in richness after a time.

That the advantage of diversification is not mere theory is shown by many practical illustrations. An interesting one is given in some detail by Goodrich.<sup>6</sup> He describes the work and gives figures on the operations of a farm in South Carolina. The owner bought a farm of  $131\frac{3}{4}$  acres which had been rented for 8 or 10 years previously and was badly run down. The fields were irregular from bushes along their boundaries, and contained some

bad gullies. The land was so poor that it had been making only 300 pounds of seed cotton or 5 to 8 bushels of corn to the acre.

The new owner of the farm filled the gullies, straightened the fields by removing brush along the edges, plowed deep, bought some barnyard manure and kept some hogs and cattle to make more, used commercial fertilizers freely, cultivated the crops well, and used the following rotation:

First year, corn, with cowpeas planted between the rows at last cultivation.

Second year, winter oats, followed by cowpeas for hay.

Third year, cotton.

The cultivated land was in three fields of 22 acres each.

From 5 to 7 tons of manure per acre was put in furrows upon which cotton beds were made, and from 700 to 1,200 pounds of commercial fertilizer was used at planting time. This fertilizer consisted of acid phosphate, cotton seed meal, and muriate of potash in the proportion of 5-5-2. About 150 to 200 pounds of nitrate of soda was also applied to the cotton about July 1. Corn was fertilized with commercial fertilizers also, about 500 pounds of a complete fertilizer being used. The oats were fertilized differently different years, but the most common treatment was 200 pounds of nitrate of soda applied in the spring.

That the cropping system used was a success is well shown by Table XLIII, which gives acre yields for 7 years. Prior to 1902 the yields were about 100 pounds of lint cotton and 5 to 8 bushels of corn.

TABLE XLIII.—CROPPING SYSTEM AND CROP YIELDS, 1902-1908 INCLUSIVE

Year	Field A		Field B		Field C	
	Crop	Yield	Crop	Yield	Crop	Yield
1902	Cotton	1.6 bales	Corn <sup>a</sup>	37 bushels	Oats <sup>b</sup>	10 bushels
1903	Corn <sup>a</sup>	50 bushels	Cotton	1.8 bales	Oats <sup>b</sup>	45 bushels
1904	Oats <sup>b</sup>	60 bushels	Corn <sup>a</sup>	65 bushels	Cotton	1.68 bales
1905	Cotton	2.14 bales	Oats <sup>b</sup>	75 bushels	Corn <sup>a</sup>	62 bushels
1906	Corn <sup>a</sup>	75 bushels	Cotton	2 bales	Oats <sup>b</sup>	60 bushels
1907	Oats <sup>b</sup>	75 bushels	Corn <sup>a</sup>	85 bushels	Cotton	1.7 bales
1908	Cotton	2.27 bales	Oats <sup>b</sup>	80 bushels	Corn	62 bushels

<sup>a</sup> Corn with cowpeas.

<sup>b</sup> Oats followed by cowpeas.

Table XLIV shows the value of products in 1908 and the total cost of production. In the costs are figured cost of labor, fertilizer, manure, seed, interest on money invested in land and machinery, and cost of miscellaneous articles.

TABLE XLIV.—TOTAL COST OF PRODUCTION AND VALUE OF PRODUCTS, 1908

Total cost of farm operation in 1908.....	\$2,855.04
<i>Value of Products</i>	
60 bales of cotton, at \$42.50.....	2,125.00
25 tons of cotton seed exchanged for 18 $\frac{3}{4}$ tons of cotton seed meal, at \$24.....	450.00
1,800 bushels of oats, at 75 cents a bushel.....	1,350.00
54 tons of oat straw, at \$10.....	540.00
44 tons of cowpea hay, at \$15.....	660.00
1,364 bushels of corn, at \$1.....	1,364.00
2 $\frac{3}{4}$ tons of pulled fodder, at \$25.....	68.75
Total value of crops produced.....	<u>\$6,557.75</u>
4,000 pounds of pork were produced having a market value of..	\$ 320.00
Estimated cost of production of pork.....	160.00
Net proceeds on pork.....	160.00
Net proceeds from farm.....	<u>\$3,862.71</u>

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## CHAPTER XXII

### COTTON SEED PRODUCTS AND OIL MILL PROCESSES

From Aug. 1, 1924, to Feb. 28, 1925, there were received at the cotton seed oil mills in the United States 4,336,101 tons of cotton seed. Valued at \$35 a ton, the seed represent a sum of \$151,763,535. The average annual receipts for the 8 years from 1918 to 1925 were 3,961,859 tons, and the value was greater, on the average, than that of the 1924 crop. This does not represent the total production of cotton seed, since about 20 per cent of the seed produced on the farms each year is reserved for planting purposes.

From the seed received from Aug. 1, 1924, to Feb. 28, 1925, the oil mills produced approximately 1,129,162,513 pounds of crude cotton seed oil, 1,716,842 tons of cotton seed meal and cake, 1,072,793 tons of cotton seed hulls, 722,686 bales and linters averaging 500 pounds each, 60,407 bales of hull fiber, and 23,026 bales of inferior lint known as grabbots. All of these products represent a value considerably in excess of \$200,000,000.

Prior to the advent of the cotton seed oil mill, or before the Civil War, cotton seed were considered of little value and were largely thrown away. Aside from the seed reserved for planting and the small amount for fertilizers and cattle feed no use was made of them. They were piled up and allowed to rot or dumped into a creek. They were often considered a nuisance around gins, and some state laws were enacted prohibiting gins from allowing them to accumulate if the gin was near a town.

All this has changed now. Cotton seed are all saved with care and marketed. Cotton seed and cotton seed products are among the main assets of the South. Lint, fuzz, hulls, oil—in fact, every part of the seed except the sand and dirt clinging to it—are used.

**Parts of a Cotton Seed.**—The seeds of nearly all the varieties of American Upland cotton have felt-like covering, the fuzz, which consists of numerous short epidermal hairs. Very commonly there are also small tufts of the longer fibers, lint which

TABLE XLV.—OIL AND PROTEIN CONTENT OF SEED OF VARIETIES OF COTTON, GROWN COLLEGE STATION, 1917  
(After Brown and Anders)

Variety	Per cent of meats or kernels	Per cent of meats or hulls	Per cent of oil in meats	Per cent of oil in seed	Per cent of oil in seeds	Total gallons oil per ton	Per cent of ammonia in meats	Per cent of ammonia in seed	Available oil per ton in clean seed, gallons	Pounds of hulls and linters per ton from clean seed	Length of lint	Per cent of lint
Dodd's Prolific	59.06	40.94	7.89	35.19	20.78	55.40	6.68	3.95	47.08	1,128.52	511.63	14.6
Trice-271-43	55.50	44.50	7.45	34.00	18.87	50.31	6.64	3.69	42.45	1,054.23	627.40	11.6
Trice-270-41	57.00	43.00	7.94	33.90	19.32	51.51	6.85	3.90	43.20	627.23	651.77	11.6
Wainman-Cleveland	51.71	48.26	7.94	33.91	17.55	46.79	6.98	3.61	39.10	1,031.38	675.65	30.6
Cleveland Big Bell	54.64	45.36	7.92	32.80	17.92	47.77	7.25	3.96	39.33	1,130.37	547.33	14.6
Cleveland-431	56.50	43.50	7.21	34.29	19.37	51.64	6.99	3.95	43.22	1,128.52	527.80	14.6
Cleveland-43	56.73	43.27	8.16	35.14	19.93	53.13	6.71	3.81	45.00	1,089.50	527.80	14.6
Cook-919	55.74	44.26	7.67	35.06	19.54	52.00	6.72	3.75	44.10	1,071.38	567.87	14.4
Miller	53.31	46.69	7.26	31.91	17.01	45.35	6.93	3.69	37.49	1,054.23	604.58	14.6
Rowden	55.50	44.50	6.69	35.43	19.66	52.41	6.54	3.63	44.67	1,054.23	604.58	14.6
One Star-15	51.50	45.50	7.83	33.93	18.49	49.29	7.19	3.92	40.94	1,119.94	627.88	14.6
One Star-132	57.50	42.50	7.78	34.90	20.07	53.51	6.69	3.85	45.30	1,099.95	560.30	14.6
One Star-X Express	54.00	46.00	7.57	36.00	19.47	51.91	6.25	3.88	44.71	1,065.67	600.00	13.5
Express-112-433	53.60	46.40	7.99	33.81	18.12	48.31	6.89	3.69	40.45	1,054.23	642.39	13.6
Express-122-433	56.00	44.09	7.39	35.11	19.66	52.41	6.71	3.75	44.32	1,071.38	535.47	13.6
Express-314	55.50	44.50	7.74	34.04	18.89	50.36	6.83	3.79	42.28	1,082.80	600.10	13.6
Express-322	55.65	44.34	7.70	34.19	19.03	50.73	6.62	3.68	42.80	1,051.38	626.94	13.6
Express-350	57.50	42.50	7.30	33.84	19.46	51.88	6.81	3.92	43.53	1,119.94	553.55	13.6
Polk	59.17	40.83	7.75	36.63	21.07	55.77	6.07	3.50	50.12	1,025.66	568.44	29.4
Kokichi	55.00	45.00	6.76	36.07	19.84	52.89	6.84	3.76	44.88	1,074.23	559.17	13.6
Foster-120	55.80	44.20	7.52	35.02	19.54	52.09	6.61	3.69	44.23	1,054.23	614.04	13.6
Foster-120-449	57.50	42.50	7.67	34.69	19.95	53.19	6.88	3.96	44.73	1,131.37	533.00	13.6
Columbia (U. S. Department of Agriculture)	56.00	44.00	6.89	34.94	19.57	52.17	6.60	3.75	44.19	1,071.38	507.19	14.4
Columbia (Sherard's)	57.50	42.50	7.56	35.84	20.61	54.05	6.28	3.61	47.26	1,031.38	614.17	13.6
Sunflower	58.00	42.00	7.38	36.04	20.90	55.72	6.46	3.75	47.73	1,071.38	570.64	13.6

a Full.

the gin failed to remove, clinging to the seeds. Beneath the fuzz is the tough, leathery seed coat, which forms the most of the commercial product known as hulls. The kernel inside the hull consists almost entirely of plant embryo. In the large much-folded cotyledons of the embryo are stored oil and other food materials which the seed contains. The reader is referred to Chap. IV for more detailed discussion of the structure of cotton seeds.

**Oil Content of Cotton Seed.**—The oil content of cotton seeds varies with the variety, locality in which the cotton is grown, soil fertility, fertilizers used, and climatic conditions. Probably the factor causing the greatest difference is the variety. Rast<sup>1</sup> in laboratory studies found a difference of 16.5 gallons of oil per ton between different varieties of cotton grown in Georgia. The difference in quantity that could be extracted in regular mill operation would be somewhat less probably, but still the difference would be large. Brown and Anders<sup>2</sup> in laboratory tests found a difference of 12.42 gallons of oil per ton between different varieties grown on the same plats in a variety test at A. and M. College, Mississippi, in 1917. Table XLV, from Brown and Anders,<sup>2</sup> gives considerable data on the content and composition of seed of a number of common varieties of cotton.

In discussing the foregoing table, the authors say:

Table XLV gives the moisture, oil, and protein content of the seed of twenty-five different strains of cotton grown at the College Station in 1917. The seed of Polk ranked highest in oil content and that of Miller lowest. Polk is a variety with small seed, low lint percentage, long staple, and rather small bolls, while Miller (a strain of Rowden) on the other hand, has large seeds, medium-high lint percentage, and large bolls. It seems that, in general, varieties having the characteristics of Polk tend to have a high oil content, while the shorter, big-boll cottons with higher lint percentage tend to have low oil content.

In further studies made by Brown and Anders,<sup>2</sup> it is shown that there appears to be a positive correlation between length of lint and oil content. In general, the varieties with longest staple have the highest oil content. When lint percentage and oil content are considered, the correlation appears to be negative. As a rule, varieties with a high lint percentage have low oil content. It appears that there is also a negative correlation between the oil content and the size of the seed. The larger seed have a

comparatively lower oil content. Varieties with a high percentage of protein rank comparatively low in oil content.

**Effect of Environmental Conditions on Oil Content of Cotton Seed.**—A great many analyses of cotton seed are made by or for oil mills each year, but, as a rule, the samples of seed tested are from mixed lots or from lots of seed whose history is uncertain or unknown. This being the case, most of the numerous analyses made are of little value in determining relationship between oil content of seed and particular environmental factors.

Creswell and Bidwell,<sup>3</sup> of the U. S. Department of Agriculture, collected data from more than 50,000 analyses of cotton seed. This mass of data reveals several interesting points. It is shown that the average production of oil per ton in the United States for the period 1916–1919 was 306 pounds. The amount ranged from 284 pounds for Texas and Oklahoma to 322 pounds for Mississippi. All the states except Oklahoma and Texas produced more than 300 pounds of oil per ton. It is probable that the more arid climate of these two states had some influence on the oil percentage. The average oil production varied considerably in different years, ranging from 296 pounds in 1918–1919 to 314 pounds in 1916–1917. This probably shows some seasonal effect. The average loss in weight per ton due to dirt, trash, and impurities was 118 pounds. The average loss was highest in South Carolina with 139 pounds, and lowest in Texas with 105 pounds.

The quality of cotton seed varies somewhat in different parts of the season. During August and September they are green and contain much moisture. Late in the season seed are sometimes damaged by rains or bad weather. The best seed come from November deliveries.

White,<sup>4</sup> of Georgia, in studies to determine the effect of soil fertilizers on the oil content of cotton seed, found that nitrogen and potassium had no effect apparently, but phosphorus increased the percentage of oil considerably, the increase being 3.6 per cent in 1911 and 5 per cent in 1912.

**Protein Content of Cotton Seed.**—Table XLV, prepared by Brown and Anders,<sup>2</sup> shows percentage of ammonia in the seed and also in the meats of the seed of a number of varieties of cotton where the varieties were grown under practically identical conditions. The percentage of ammonia in the meats ranges from 6.07 for the Polk variety to 7.25 for Cleveland Big Boll. Wells and

Smith,<sup>5</sup> of Georgia, report a variation of 1.06 per cent in nitrogen between certain short-staple varieties they studied in Georgia. Mexican Big Boll was next to lowest with a nitrogen percentage of 5.21, while Wannamaker Cleveland was near the top with a percentage of 6.15.

**Cotton Seed Oil Mills in the United States.**—In 1783, a society in London known as the Society of Arts came to the conclusion that the oil contained in cotton seed is of commercial value and voted to encourage an invention by means of which it might be extracted.

In 1826, Benjamin Waring of Columbia, S. C., expressed oil from cotton with crude machinery. This was probably the first instance in America. In 1829, General David R. Williams of Society Hill, S. C., also built a machine for the manufacture of cotton seed oil. From that time until the period of the Civil War the industry was largely in an experimental stage. In European countries considerable advancement had been made, but there the problem of oil extraction was not such a difficult one, since the millers crushed seed of Egyptian and Sea Island cotton—varieties with smooth seeds. The seed of most American varieties were covered with a heavy coating of fuzz which absorbed much oil when the seed were compressed. At the outbreak of the Civil War there were but seven oil mills in the United States. By 1870 the number had increased to twenty-six.

From 1870 to 1890 improvements in the extraction of crude oil as well as in its refinement came along steadily. More efficient delinting machines were invented, and edible oils were discovered, which found a ready market in foreign countries. By 1890 the number of oil mills had increased to 119; the production of crude oil increased from 547,165 gallons in 1872 to 13,384,385 gallons in 1890. The amount of the cotton seed crushed increased from 4 to 25 per cent. The value of a ton of seed increased from 40 cents to \$4.80. The total value of the products obtained from the seed increased from \$293,546 to \$5,291,178.

From 1890 to 1900 several further improvements in the methods of extracting oil were made, including better methods of cooking the meats and the use of the hydraulic press for expressing the oil. The combining of cotton seed oil with beef fat to make lard compound and artificial butter and its further use for packing sardines increased the demand for refined oil. The

number of mills increased to 357 during that period, and their combined output at the close of the period represented 46,902,-390 gallons of oil annually. The value of seed had risen to \$11.60 per ton, and 53 per cent of the production was crushed. By 1900, other cotton seed products had become of much importance. In that year the oil mills produced 884,000 tons of cotton seed meal, 1,169,000 tons of hulls, and 114,544 bales of linters.

From 1900 to the present time still other improvements in manufacturing have been made and new uses found for the products. Processes have been discovered by means of which the oil can be hardened and deodorized, thus increasing its use for human consumption. It has been found that the meal and hulls, if properly fed, afford excellent food for animals. Quantities of linters have been used in making explosives and a great deal is used in making artificial silk. There are now more than 800 oil mills in the South, which crush about 80 per cent of the cotton seed grown. The other 20 per cent is reserved for planting. The total value of the product from these mills, as was shown, represents an annual value of more than \$200,000,000. This is an enormous sum, when the fact is considered that a few decades ago cotton seed was considered practically worthless.

**Marketing Cotton Seed.**—The price paid by oil mills for cotton seed is determined largely by the value of oil and other seed products in the larger markets of the country. The mill knows within a narrow margin just what it can get out of a ton of seed, and it knows too the cost of milling, and so fixes the price per ton accordingly. Competition for seed is keen and the margin of profit is narrow.

Some seed is hauled in wagons from gins near by, but the greater part received by larger mills comes in car lots. Larger plantations near railroads usually so locate their gins that they can blow seed from the gin into a car and sell it by the car load. Most of the larger mills have buyers at railway stations remote from oil mills who buy small lots of seed and ship by the car load.

When a car of seed arrives at the mill, it is sampled in different parts. These samples are put together and a composite sample taken from them to represent the car. This sample is tested by a disinterested party for foreign matter, moisture, and damaged and immature seed. According to the rules of the Interstate Cotton Seed Crushers' Association, deduction may be made in the price to be paid for the seed if there is foreign matter in the

seed in excess of 1 per cent, moisture in excess of 10 per cent, or damaged or immature seed in excess of 6 per cent. The deductions are on the basis of a scale adopted by the Crushers' Association.

**Storage of Cotton Seed.**—The storage of seed is a problem of considerable importance to oil mills. Large quantities of seed are needed to keep the mill going, but if large amounts are bought and stored in bulk, or loose, they are apt to heat and deteriorate. This is especially true if the seed are green or contain an undue amount of moisture. The heating results in a decided increase in the free fatty acid in the oil. Rather<sup>6</sup> found that seed in storage which heated to a temperature of 111°F. increased in free fatty acid content from 2.26 to 11.89 per cent. Free fatty acid in cotton seed oil is objectionable and must be removed in refining processes. If present in the oil in quantity, there is considerable loss. If the heating of the seed is considerable, there may be a further chemical reaction which will result in loss of nitrogen and thus lower the value of the meal that is to be made from the seed.

If the seed cotton is allowed to remain in the small cotton houses on the plantations for 2 or 3 weeks after picking, or until thoroughly dry, there is not so much danger of the seed heating in the milling processes later. Or if the green seed from the gin are stored in small lots, say a ton or less, for a few weeks, there is not much heating later. Mills usually have large seed houses, so that the seed may be scattered throughout considerable space. As far as possible, bulk seed received by the mills are crushed soon after they arrive to avoid deterioration. If a lot of seed is beginning to heat, it is thrown into the conveyors and used at once.

**Oil-mill Processes and Machines.**—The following discussion of the various machines used in oil mills must be considered to apply in general. Nearly every mill will have one or more machines of a type different from the one described, and the process followed may be somewhat different from the one outlined. In the limited space available an exhaustive discussion is, of course, not possible.

**Cleaning Seed.**—When a lot of cotton seed arrives at the oil mill, it contains considerable foreign matter, which must be removed before the seed are put through the milling processes. These impurities include dirt, sand, cotton burs, locks, unginned seed, pieces of metal, and other foreign matter. To remove

these the seed is put through different machines which will be described briefly.

The seed are transferred from the seed house to the first cleaning machine, the sand-and-boll screen, by an auger conveyor, which runs the whole length of the house, and by bucket elevators. The sand-and-boll screen consists essentially of an inclined reel covered with revolving screens of various-sized mesh (Fig. 119). The seed are fed into the higher end of the reel, and as they are moved toward the lower end there is a selective separation of seed and foreign matter according to size. The unginned

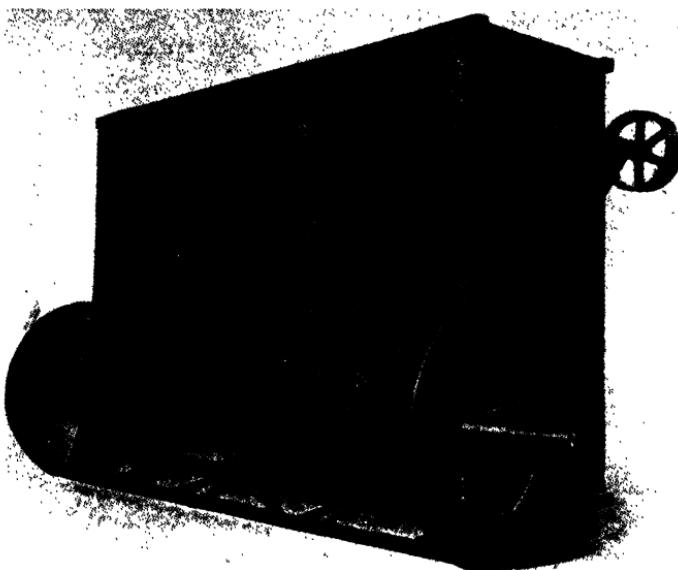


FIG. 119.—Sand-and-boll screen. (*Courtesy Atlanta Utility Works.*)

cotton locks and burs pass on through the reel. This miscellaneous mass of material is collected and saved for ginning. The lint obtained is, when ginned, of low grade and inferior, but is in sufficient quantity to be of commercial importance. This inferior lint is known as "grabbots." Dirt and sand pass through fine openings in the screen in the upper part of the reel, while the seed pass through larger meshes in the power part. From the sand-and-boll screen the seed are commonly passed over a shaker screen, which removes other foreign matter. In this machine, or in another adjacent to it, the seed are subjected to the action of a

blower, a strong current of air, which separates out other foreign matter yet remaining. The size and the pattern of cleaner used vary considerably, of course, in different mills, depending on the capacity of the mill and whether or not the most recent types of machines are used.

*Delinting.*—After the seed are cleaned as thoroughly as possible, they are passed on to machines known as delinters for the removal of a part of the fuzz clinging to the seed. These machines work on the same principle as cotton gins and are similar in structure. They differ from the cotton gin in that the saws have finer teeth and are set closer together.

The fuzz, or linters, is removed from the seed so that it will not absorb oil when the seed are pressed. Without the linters the hulls are of higher value as livestock feed. Not all the fuzz is removed from the seed; some of it is left to cause the hulls to cling together more or less when they are separated from the meats in the hulling process. From 40 to about 80 pounds of linters per ton are removed from seed in ordinary commercial operations, but it is possible to remove as much as 200 pounds, as was sometimes done during the World War, when there was a great demand for linters for making explosives. The average cut is about 65 pounds. As linters are worth from 3 to 6 cents a pound, their commercial value is another reason for their removal from the seed.

All American Upland varieties of cotton grown at present, or at least all that are grown extensively, have seed covered with fuzz, which makes delinting necessary. Sea Island cotton and certain foreign varieties have smooth seeds, which require no delinting, but because of this lack of fuzz it is difficult to remove the hulls from the meats. The seed of these varieties are frequently compressed without removing the hulls. This method gives a lower grade of oil since it is discolored by coloring matter from the hulls.

*Hulling.*—After the seed have had the required amount of fuzz removed by the delinting machines, they are next carried to a machine known as huller for removal of the hull from the kernel, or meat. This is accomplished by subjecting them to the action of a machine containing two sets of knives, one stationary and the other on a rapidly revolving plate or cylinder. The knives are so adjusted that when the plate revolves they almost touch (Fig. 120). The huller cracks, breaks, or cuts the hull

and kernel so that the kernels may be separated from the hulls. It must not mash or compress the seed, for that would result in a loss of oil from the kernel. If the seed is dry, the kernel is loose inside and is easily separated from the hull, which is then brittle and easily cut or broken. If the seed is damp, the hull is tough and the seed is liable to be crushed before the hull can be cut.

*Separating Meats and Hulls.*—The seed that come from the huller are cut into rather small pieces. The next step in the milling process is to separate these pieces of hulls and meats.

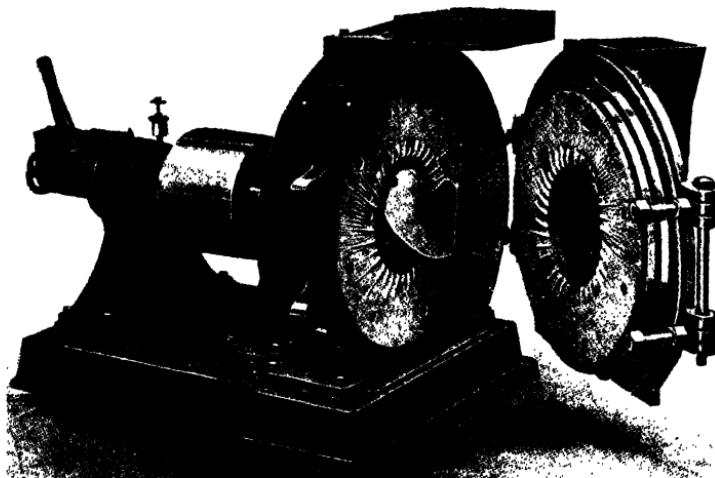


FIG. 120.—Disc cotton seed huller.

This is accomplished by passing the material over a shaker screen, which has perforations large enough for the pieces of meats and but little of the hulls to pass through.

The hulls are next carried to a beater, where they are pounded up to loosen any additional pieces of meats that may be clinging inside. These remaining pieces of kernel are separated from the hulls by perforated screens over which the hulls pass on their way to the hull bin. In the bin the hulls are next sacked in 100-pound bags for the market.

The meats, in which there is still a small amount of little pieces of hulls, are next passed under one or two suction blasts, which may be set so as to remove just the quantity of hulls desired. It is by this means that the ammonia content of the meal is

regulated. The meal made from pure kernels is too rich in nitrogen to meet trade demands.

*Crushing.*—From the hull and meat separator the cleaned kernels are transferred to a crusher. This consists essentially of a series of large iron rollers placed one above another and so arranged that they revolve in contact (Fig. 121). The kernels are fed between the two upper rollers and pass in succession between every pair. The object of this crushing is to rupture every cell in the kernel structure, so that the cell contents may cook evenly and the oil within the cell may find easy egress.

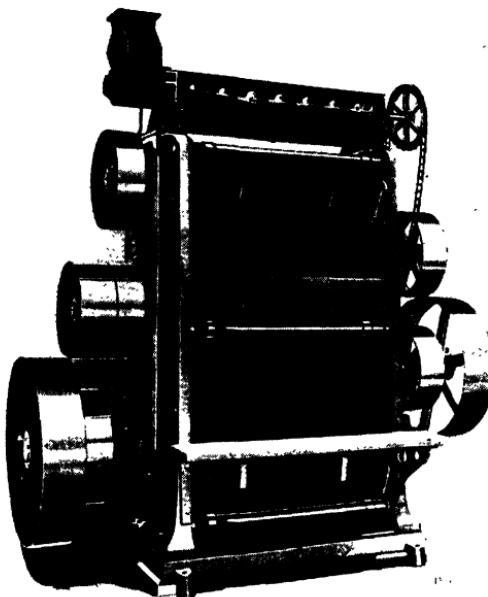


FIG. 121.—Cotton seed crusher. (*Courtesy French Oil Mill Machinery Company.*)

*Cooking.*—From the crusher the pulverized kernels are carried to a heater, or cooker. This consists of a set of four or five steam-jacketed iron drums having a diameter of 52 to 72 inches and a depth of 14 to 18 inches. These drums are stacked one above the other and resemble a large iron boiler built in sections (Fig. 122). The bottom of each drum contains a trap door, through which the contents of an upper drum may pass to the one below. Each drum is also equipped with a pressure gage to govern the steam or temperature, a steam trap for the removal of moisture, and an agitator to stir the meats.

The meats are first placed in the top drum where they are heated to a temperature of about 140°F. The temperature is gradually increased in successive drums until a temperature of 220°F. is reached in the bottom drum. The meats are allowed to remain in each drum from 15 to 40 minutes, the length of time varying with the moisture in the seed which must be expelled.

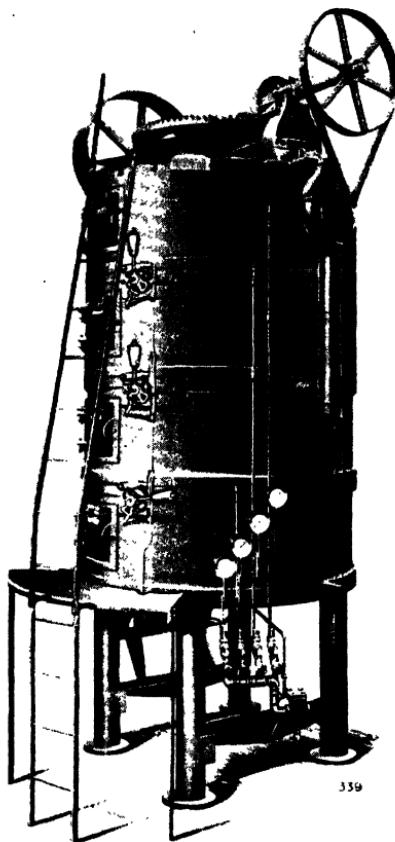


FIG. 122.—Cooker. (*Courtesy French Oil Mill Machinery Company.*)

If the seed are very dry, it may be necessary to moisten them slightly with steam to facilitate cooking. Cooking is a particular process. Success depends largely on the judgment of the cook. There are no definite rules that can be followed.

Cooking the meat pulp serves several purposes. It drives out excess moisture, modifies the consistency of the pulp so that the

maximum amount of oil may be extracted, increases the fluidity of the oil, and coagulates the albumen of the seed.

*Cake Forming.*—From the cooker, the seed pulp is transferred to a receptacle known as the subheater, which holds the material and preserves its temperature until it is placed in the cake former (Fig. 123). The cake former consists of a carriage which takes a measured quantity of the cooked meats from the subheater to a cast-iron mold, usually 14 by 32 inches in breadth and length. This mold is lined with a strong press cloth made of animal hair. After the pulp is put into the mold, the cloth is folded over its upper surface so that it is entirely surrounded by the cloth. A limited amount of pressure is then applied to the wrapped mass,

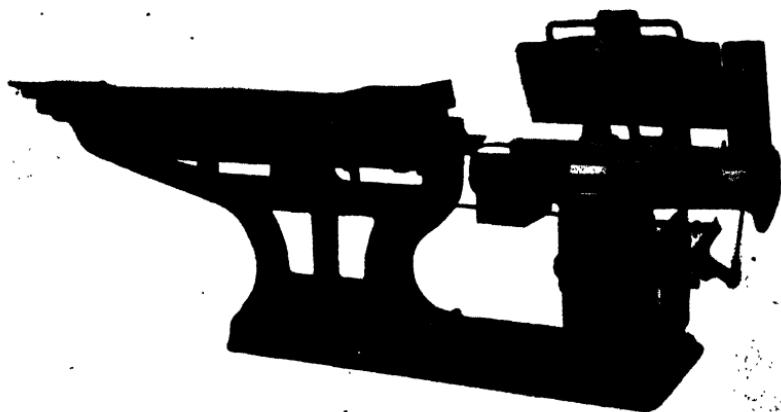


FIG. 123.—Cake former. (*Courtesy French Oil Mill Machinery Company.*)

sufficient to set the cake but not enough to start the oil within the pulp to flowing. After the pressure is removed, the iron tray containing the wrapped pulp is lifted by hand and placed in an empty compartment of the hydraulic press. The tray is then withdrawn, the wrapped pulp being left for compression.

*Hydraulic Press.*—The hydraulic press (Fig. 124) contains fifteen compartments, one on top of another, into which the trays containing cooked meats are inserted. Pressure is applied from below by means of a hydraulic ram. The pressure is applied gradually, about 400 pounds per square inch until the slack is taken up and the cakes set, and then it is increased to about 4,000 pounds per square inch. The length of time in the press varies with the relation of the capacity of the cooker and presses,

but is usually 24 to 30 minutes. A large mill has several presses like the one shown in Fig. 124. Figure 125 shows a view in a mill in Japan where soy beans are crushed for oil. The equipment is the same as for cotton seed. At the extreme left is a cooker; between the workmen is a cake former; and at the right several presses.

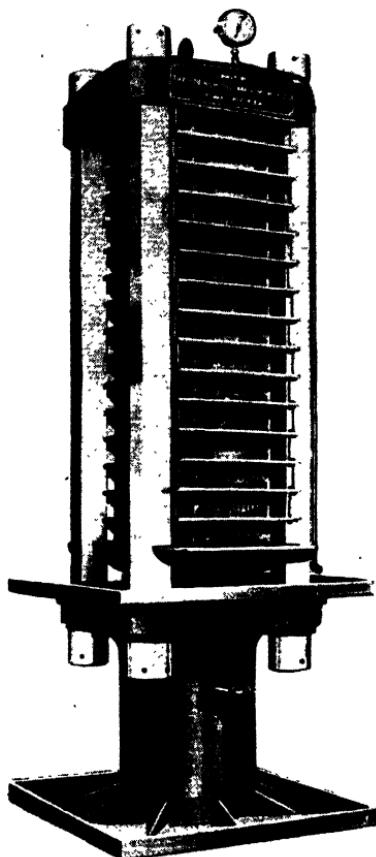


FIG. 124.—Hydraulic press. (Courtesy French Oil Mill Machinery Company.)

The crude oil from the presses is carried by gravity to a tank below. From here it passes through a filter press or settling tanks into storage tanks or to large tanks on cars for shipment to refineries.

*Cake Grinding.*—After the oil is extracted, the pulp left is removed from the press and unwrapped. It is now in the form of

firm cakes weighing 12 to 14 pounds each. These cakes are stacked to dry for at least 24 hours. Some of the cake is sold on the market and used for feed for livestock in this form. As a rule, the cakes are ground to form a meal known as cotton seed meal. The cakes are first broken into small pieces by a machine known as a cake breaker, and next ground into a fine meal by a grinding mill. The meal is sacked in 100-pound bags for the market.

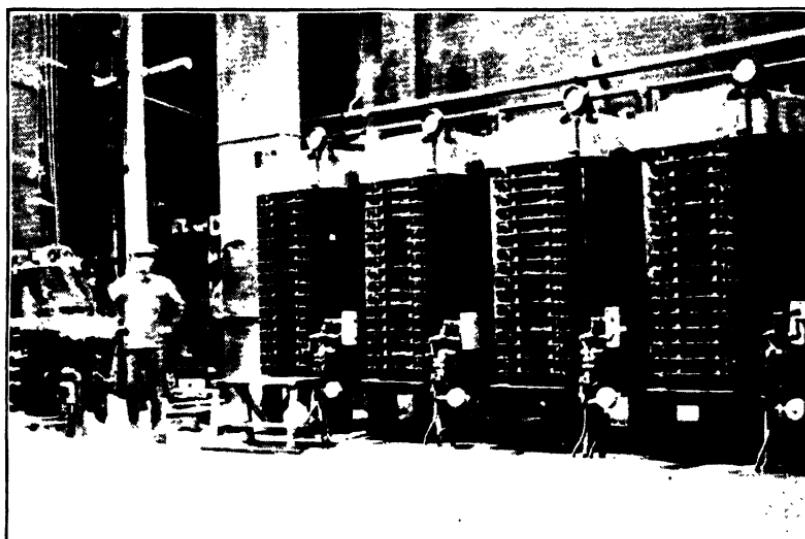


FIG. 125.—Press room, Nisshin Oil Mills, Yokohama, Japan. (Courtesy French Oil Mill Machinery Company.)

**Products from a Ton of Cotton Seed.**—Based on Bureau of Census figures for the years 1914-1915 to 1918-1919 inclusive, Sheets and Thompson<sup>8</sup> give the following figures for the quantity of raw products obtained from a ton of cotton seed:

	POUNDS
Linters, or short fiber.....	110
Hulls.....	514
Cake or meal.....	954
Crude oil.....	303
Loss in manufacture.....	119
Total.....	2,000

Since the figures cover the war period, during which a heavy cut of linters was made, the amount of linters given is considerably

above the average obtained, which is about 65 pounds. This extra weight of linters, about 45 pounds, ordinarily goes to increase the weight of the hulls. The average hull weight at present is about 559 pounds.

**Linters.**—Of the several crude products from cotton seed, linters is one of the most important. The origin and development of cotton fuzz, or linters, were discussed in Chap. VII, and methods used in delinting seed were given on a preceding page of this chapter. Their character, uses, and marketing will now be considered.

The fiber of linters is very short, ranging from  $\frac{1}{8}$  to  $\frac{1}{2}$  inch in length, but there is also material mixed with the fibers that is too short to measure. Linters vary in color, ranging from gray, yellow, and green to brown. The color depends largely on the closeness of the cut. If much fuzz is removed from the seed, the color is darker, because more coloring matter is obtained from seed coat and there is more dust and other foreign matter mixed with the linters. As brought out by Agelasto,<sup>7</sup> the oil mill can vary the grade of linters at any time by varying the number of pounds cut from a ton of seed.

In 1900, the United States produced 114,000 bales of linters. This was 1.2 per cent of the cotton crop. The production gradually increased until in 1910 it was 313,000 bales, which was 2.9 per cent of the crop. Following this, the increase was gradual until the period of the World War, when the production increased greatly; in 1917, there were 1,331,000 bales, which was 10.9 per cent of the cotton crop for that year. Since the war, the production has decreased somewhat, but it is still considerable. From Aug. 1, 1924, to Feb. 28, 1925, 722,686 bales were ginned.

Linters are packed in 500-pound bales very similar to cotton bales. Samples are drawn from the bales in much the same way as they are taken from ordinary bales except that with linters they are taken from all four sides of the bale. Bales of linters are bought and sold by certain cotton factors. Trading is mostly done on the basis of types or samples presented.

There are numerous uses to which linters are applied, and the number is increasing. The following outline from Agelasto<sup>7</sup> gives in brief most of the uses. Most of the product is used, however, in making explosives and mattresses.

Linters are used for	Batting	Mattresses Pads Cushions Comforts Horse collars Upholstery
	Wadding	
	Stuffing material for	Absorbent cotton Mixing with shoddy Mixing with wool in hat making Mixing with lamb's wool for fleece-lined underwear
	Felt	
	Low-grade yarns	Lamp and candle wicks Twine Rope Carpets
	Cellulose	Artificial silk Paper Basis for explosives

**Cotton Seed Hulls.**—As was mentioned on a preceding page, under the present milling system a ton of cotton seed yields about 559 pounds of hulls. The amount or weight varies with the cut of linters and the grade of meal made. The total production in the United States is about 1,000,000 tons annually. In 1924-1925 it was 1,072,793 tons. This represents a value of \$10,000,000 to \$15,000,000.

Sheets and Thompson<sup>8</sup> give the following analysis of cotton seed hulls: water, 8.5 per cent; ash, 2.4 per cent; protein, 2.8 per cent; fiber, 48.6 per cent; nitrogen-free extract, 37.4 per cent; and fat, 0.3 per cent. Cotton seed hull ashes, as given by McBryde,<sup>9</sup> contain phosphoric acid, 9.08 per cent; potash, 23.40 per cent; and lime, 8.85 per cent.

Prior to 1900 cotton seed hulls were burned largely as fuel for oil-mill boilers. The ashes, when pure, were used considerably as fertilizer, since they were comparatively rich in potash. At present hulls are used chiefly as food for cattle. They are not very nutritious, being less so than oat straw or corn stover, but serve as roughage when nothing better is available, and are useful for mixing with cotton seed meal, which is a very rich feed. They are also used as a constituent of ground mixed feeds.

Cotton seed hulls from which the lint has been removed are sometimes ground to make what is known as cotton seed

hull bran. The feeding value of the bran is similar to that of hulls.

**Cotton Seed Meal.**—In a preceding part of this chapter the manufacture of cotton seed cake and the grinding of cake to make meal were explained.

Cotton seed meal, the grades of meal, and certain other cotton seed products are defined and classified as follows by the Association of Feed Control Officials of the United States:

*Cotton seed meal* is a product of the cotton seed only, composed principally of the kernel with such portion of the hull as is necessary in the manufacture of oil; provided that nothing shall be recognized as cotton seed meal that does not conform to the foregoing definition and that does not contain at least 36 per cent of protein.

*Choice cotton seed meal* must be finely ground, not necessarily bolted, perfectly sound and sweet in odor, yellow, free from excess of lint, and must contain at least 41 per cent of protein.

*Prime cotton seed meal* must be finely ground, not necessarily bolted, of sweet odor, reasonably bright in color, yellow, not brown or reddish, free from excess of lint, and must contain at least 38.6 per cent of protein.

*Good cotton seed meal* must be finely ground, not necessarily bolted, of sweet odor, reasonably bright in color, and must contain at least 36 per cent of protein.

*Cotton seed feed* is a mixture of cotton seed meal and cotton seed hulls, containing less than 36 per cent of protein.

*Cold-pressed cotton seed* is the product resulting from subjecting the whole undecorticated cotton seed to the cold-pressure process for the extraction of oil, and includes the entire cotton seed less the oil extracted.

*Ground cold-pressed cotton seed* is the ground product resulting from subjecting the whole undecorticated cotton seed to the cold-pressure process for the extraction of oil, and includes the entire ground cotton seed less the oil extracted.

In most oil mills the cotton seed cake, or meal, is tested on the ammonia basis. To determine the percentage of protein in the cake, the ammonia content given is multiplied by 5.15. To illustrate, if the analysis shows 7.5 per cent ammonia, the per cent protein is  $7.5 \times 5.15$ , which is 38.62, or 38.62 pounds of protein in 100 pounds of cake. If the analysis is given in terms of nitrogen content, the percentage of protein is determined by multiplying the nitrogen figures by 6.25.

Sheets and Thompson<sup>8</sup> give the following table showing nutrients in cotton seed and cotton seed products.

TABLE XLVI.—PERCENTAGE COMPOSITION OF COTTON SEED PRODUCTS  
(Pounds of nutrients in 100 pounds)

Product	Water	Ash	Crude protein	Carbohydrates		Fat (ether extract)
				Fiber	Nitro- gen-free extract	
Cotton seed.....	6.6	3.7	21.7	19.7	26.9	21.4
Cotton seed meal:						
Choice.....	6.4	5.9	43.3	10.0	25.7	8.7
Prime.....	6.6	6.1	38.9	13.2	28.5	6.7
Good.....	6.5	5.8	37.8	13.6	30.6	5.7
Cold-pressed cotton seed cake.....	6.2	4.7	25.8	24.0	31.5	7.8
Cotton seed hulls.....	8.5	2.4	2.8	48.6	37.4	0.3

Lamborn<sup>10</sup> gives the fertilizing constituents of cotton seed meal as follows: nitrogen, 6.79 per cent; phosphoric acid, 2.88 per cent; potash, 1.77 per cent. These figures are based on 204 analyses.

The annual production of cotton seed meal and cake in the United States for the 6-year period 1918-1923 was 1,943,430 tons. This represents an enormous value, since the average market value of meal is about \$40 a ton and has ranged as high as \$67 a ton within the past 10 years.

**Use of Cotton Seed Meal and Cake.**—The chief use of cotton seed meal and cake is for feeding livestock. Because of their rich protein content, they are very nutritious and are valuable foods if properly fed. The meal is used in the United States chiefly, but for feeding on the ground or for feeding on the range when the wind is blowing the cake is more desirable. Much cake is used in foreign countries.

Cotton seed meal is especially good for cattle, being excellent feed for both dairy and beef animals. Best results are obtained when the meal is given with other feeds, such as corn silage and bran, which are not so rich in protein. It may be fed to mules in limited quantities to good advantage. It may also be fed to horses, sheep, and hogs if fed cautiously. Meal contains a toxic substance, or poison, known as gossypol. This is injurious to all animals if taken in sufficient quantity for a period of time, but

cattle can eat a moderate amount of meal indefinitely without injury. Other animals are more susceptible to the injurious effects. This is especially true of hogs. If meal is fed to them for more than 5 or 6 weeks, harmful results are very likely to follow.

Cotton seed meal was formerly used considerably as a fertilizer, but its present value for feeding purposes is such as practically to prohibit such use.

**Crude Cotton Seed Oil.**—Cotton seed oil as it flows from the press contains some impurities—water, a little meal, albumen, free fatty acids, coloring matter, etc. Most of these impurities may be eliminated or lessened by proper management in the cooking process and by means of settling tanks or filtration. The coloring matter and free fatty acids can be removed at the refinery only.

Cotton seed oil is fluid at ordinary temperatures, but the fatty acids require a temperature of from 95 to 122°F. for melting. The freezing point is 53°F. to several degrees lower. When the freezing-point temperature is reached, the stearin in the oil separates from the rest. This is helpful in certain manufacturing processes, but is not desirable when the oil is on the way to the refinery. To avoid this separation, tank cars are provided with steam pipes for heating the oil if necessary during cold weather.

Crude cotton seed oil is classified by the Interstate Cotton Seed Crushers' Association as "Choice," "Prime," and "Off." Choice Crude cotton seed oil is defined as follows:

Choice Crude cotton seed oil must be pressed from sound decorticated seed; must be sweet in flavor and odor, free from water and settling, and must produce, when refined by these rules (Rules of the Interstate Cotton Seed Crushers' Association), Choice Summer Yellow oil at a loss in weight not exceeding 6 per cent.

Prime Crude cotton seed oil is defined the same as Choice Crude cotton seed oil, except that the loss in weight in producing Prime Summer Yellow oil must not exceed 9 per cent. Oil that is neither "Choice" nor "Prime" is "Off."

The average annual production of oil in the United States for the years 1918–1923, as given by the U. S. Department of Commerce, was 1,191,531,151 pounds. The market value per pound during the past 10 years has ranged from  $3\frac{3}{4}$  to 22 cents. The price recently has been 8 to 10 cents a pound.

**Refined Cotton Seed Oil.**—Some oil mills have refineries in connection with the mill, but, as a rule, the oil is shipped to refineries elsewhere. The oil is transported in tank cars, 60,000 pounds making a car load.

Refined cotton seed oil differs from crude oil in that most of the free fatty acids, coloring matter, and other impurities have been removed from it. In the refining process the crude oil is placed in a large iron tank, a solution of caustic soda is poured on it, and the two are stirred and mixed by agitator. After they are mixed thoroughly, the temperature is raised to 120 to 140°F. The impurities go to the bottom as settling. The purified oil has a yellow appearance and is drawn off. The settling are sold as soap stock. The yellow oil contains some of the caustic soda. To free it of this alkali, it is run into a finishing tank, where the soda is washed out with water.

Summer Yellow oil is classified into several different grades: Choice Summer Yellow, Prime Summer Yellow, Good Off Summer Yellow, Off Summer Yellow, Reddish Off Summer Yellow, etc. The classification depends on the color, flavor, odor, and percentage of free fatty acid.

According to the rules of the Interstate Cotton Seed Crushers' Association, Choice Summer Yellow cotton seed oil must be sweet in flavor and odor, prime in color, clear and brilliant in appearance, and free from water and settling, and shall contain not more than one-eighth of 1 per cent free fatty acid.

**Use of Cotton Seed Oil.**—Large quantities of cotton seed oil are mixed with animal fats to make a lard compound which is used as a substitute for hog lard. Much is also used in making oleomargarine, a butter substitute. Low grades of oil, and better grades also if the market price of oil is low, are used in making soap. Some oil is mixed with petroleum to make miners' oil, the oil that miners use in their lamps in the mine. Some is used for packing sardines. A considerable quantity is used also as a table or salad oil.

**Numerous Uses of Cotton Seed Products.**—The number of uses to which different cotton seed products are put is now legion; yet new uses are being discovered yearly. A full discussion of this subject would require a volume. The following outline published by the U. S. Department of Agriculture will give the reader some notion of the numerous uses.

Linters		Battting Wadding	Pads Cushions Comforts Horse collars Mattresses Upholstery
Absorbent cotton Mixing with shoddy Mixing with wool in hat making Mixing with lamb's wool for fleece-lined underwear		Stuffing material for	Felt
Felt		Lamp and candle wicks Twine Rope Carpets	
Low-grade yarns		Writing paper <sup>a</sup> Guncotton, nitrocellulose, or pyrocellulose	
Hulls		Cellulose	
Feed		Writing paper <sup>a</sup> Guncotton, nitrocellulose, or pyrocellulose	
Fertilizer		Smokeless powder	
Fuel <sup>a</sup>		Varnishes	
Packing		Coating for metals Artificial leather Waterproofing	
Household utensils		Pyroxylin	
Bran—cattle feed		Varnishes	
Cotton seed		Celluloid Collodion Varnishes Artificial silk Photographic films	
Fiber		Plastics	
Fiber		Stuffing for horse collars Basis for explosives	
Fiber		Cellulose—used same as under Linters	
Fiber		Paper stock—pressed-paper products	
Fertilizer		Fertilizer	
Dyestuffs		Dyestuffs	
Meats		Cattle Poultry <sup>a</sup> Horses and mules Swine <sup>a</sup> Sheep Bread Cake Cracker	
Meats		Feed for	
Meats		Cosmetics Bleached or deodorized oil	
Meats		Animal compound lard Cooking oil Salad oil	
Meats		Hydrogen- ated oil	
Meats		Lard substitutes Synthetic stearin—vegetable-compound lard	
Meats		Prime Sum- mer Yellow oil	
Meats		Cold- pressed oil	
Meats		Salad oil Setting olives Winter oil Packing sardines Winter white oil	
Meats		Stearin—oleomargarine	
Meats		Emulsion for medical purposes	
Meats		Substitute for sweet oil	
Meats		Deodorized oil	
Crude oil		Off-grade Summer Yellow oil	
Crude oil		Soap Miners' oil	
Crude oil		Hydrogenated oil—synthetic stearin—soap	
Putty		Washing powder	
Putty		Glycerin—nitroglycerin	
Froots		Candle- pitch	
Froots		Stearic acid— candles	
Froots		Washing powder	
Froots		Soap	
Froots		Stearin pitch or cotton oil pitch	
Froots		Roofing tar	
Froots		Composi- tion roof- ing	
Froots		Linoleums	
Froots		Insulating materi- als	
Froots		Oilcloth	
Froots		Waterproofing	
Froots		Cheap-paint base	
Froots		Cotton rubber	
Froots		Uphol- stering	
Froots		Artificial leather	
Froots		Book- binding	
Froots		Fulling ware	

<sup>a</sup> Possible uses to which small quantities only are devoted.

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## CHAPTER XXIII

### USES AND SPINNING QUALITIES OF VARIOUS KINDS OF COTTON

The subject of this chapter is a rather difficult one to discuss, because there is much variation in the staple lengths and grades used by different mills in making one kind of goods. The quality of the goods made varies considerably with the grade and the staple of the cotton spun. Changes in price of cotton or in economic conditions bring about some changes in products turned out. It is also difficult to get reliable data on just what is used by different mills in making their products. They feel that this information is a trade secret and are loath to give it out. Also, the methods used in practical work are frequently improved or changed.

**How Cotton Yarns Are Measured.**—Before cotton fibers can be woven into cloth, they must be spun into threads, or yarns. Yarns differ considerably in size or fineness, the finer grades being used in making laces and delicate fabrics. The size of a yarn is indicated or measured by counts. The count is determined by the number, or count, of hanks of any particular yarn that are required to weigh a pound. A hank of yarn contains 840 yards. To illustrate, a yarn designated as 20's requires twenty hanks of 840 yards each to weigh a pound. The counts range from 1's to 200's in practical work. In rare instances they may run as high as 700's.

**Staple Lengths Used in Making Different Counts of Yarn.**—Howarth,<sup>1</sup> on the basis of the size of the yarn, groups yarns into five classes: thick, coarse, medium, medium-fine, and fine. The thick yarns are of counts up to 10's. Short-stapled cottons and cotton waste, that is, short fibers combed from longer cottons by mill machines, are used chiefly in making the thick yarns. The coarse yarns range up to 22's. Short-staple varieties from India and ordinary American short-staple Uplands are used in spinning these yarns. The medium yarns have counts that run up to 46's, and staples from  $1\frac{1}{16}$  to  $1\frac{1}{4}$  inches in length are used in making

them. These come from American Binders and Long Staples, Upper Egyptians, and similar cottons. The medium-fine yarns range approximately from 46's to 80's, Egyptian and Sea Island cottons being used in making them. The longest and most uniform staples grown are used in making the fine yarns whose counts range from 80's up to 400's or higher.

**Fabrics Made from Different Counts of Yarn.**—In general, coarse fabrics are made from the thicker or heavier yarns, and finer fabrics from the higher counts. The quality of cloth desired determines what is to be used. One kind of goods may vary greatly in quality, ranging from coarse to fine. Some goods made from yarns ranging in counts from 12's to 20's are sheeting, some grades of calico, some domestic, toweling, cords, fustians, corduroys, etc. Shirting and gingham are made from various yarns the class depending on the fineness of the goods wanted. Sateens are made from yarns ranging from 36's to 80's. Mulls range from 60's to 100's, and cambrics from 80's to 160's. The yarns of highest counts are used for making laces and the finest fabrics.

**Character of Cotton Desired by Spinners.**—While it is true that there is great variation in the kind or quality of cotton wanted by different mills on account of their varied product or the many kinds of goods made, there are certain qualities which are generally sought. These are summarized by Howarth<sup>1</sup> as follows:

First, and most important of all: The fibers must be even in length. Secondly: The cotton must be ripe.

Thirdly: The grade must be even.

Fourthly: The cotton must be as free as possible from dead cotton, bearded motes, seed, fibers other than cotton, sand, iron, stones, excessive moisture, and other foreign substances.

If long-staple and short-staple cottons are mixed and an attempt is made to spin the mixture, the long fibers will wrap and clog the machines if they are set for the short fibers. If the machines are set for the long fibers, a part of the short fibers will be discarded as waste; others will ride on the longer fibers without being drafted at all. The result will be an irregular thread with thick and thin parts.

Unripe fibers lack strength and twist. A part of the weak fibers are broken in the spinning process. Some of the pieces

go into the waste; others get rolled together and make nep, or knots on the threads. Some of the weak or unripe fibers pass through unbroken, but the resultant yarn is less strong because of their presence, and it is more difficult to dye uniformly fabrics made from such yarns. If the fibers lack twist, they will not cling well, and consequently the machines cannot be run at maximum speed. The mill workers will not be able to turn out the usual number of pieces; so the total output of the mill will be lowered.

As a rule, evenness of grade in a lot of cotton is not so important as evenness in length of staple or the ripeness of fibers; yet it is a matter of considerable importance to mills which produce yarns used in making a standardized cloth, a cloth finished in a particular color, or a cloth which retains the natural color of the cotton.

**Comparative Waste, Tensile Strength, and Bleaching Qualities of Cotton Belonging to Different Grades of Upland White Cotton.** Dean and Taylor<sup>2</sup> made manufacturing tests of cotton representing Middling Fair, Good Middling, Middling, Low Middling, and Good Ordinary of the Official Cotton Standards to determine the relative values of the different grades. Cotton from 109 bales collected from different parts of the Cotton Belt was tested both in a cotton mill and in a textile school. By this means comparison was made of the spinning qualities of cotton from different sections of the Cotton Belt. It was found in the mill tests that the percentage of combined visible and invisible waste of cotton from east of the Mississippi River ranged from 8.63 for Middling Fair grade to 15.64 for Good Ordinary. The waste from the intermediate grades was intermediate, as may be seen from Table XLVII. The cotton grown west of the Mississippi River was about 1 per cent more wasty than the other. The strength of the yarns of the eastern cotton was found to decrease from 74.6 pounds per skein for Middling Fair grade to 68.0 pounds for Good Ordinary. The western cotton was slightly stronger, ranging from 83.9 to 74.9 pounds per skein.

After making allowance for difference in moisture conditions prevailing where the tests were made, the results from the textile school tests agreed very closely with the results from the mill tests.

Bleaching tests made by Dean and Taylor<sup>2</sup> showed that goods made from Middling Fair and Good Middling grades, when

TABLE XLVII.—COMBINED VISIBLE- AND INVISIBLE-WASTE PERCENTAGES OF FIVE GRADES OF BOTH EASTERN UPLAND AND WESTERN UPLAND COTTON (MILL TESTS) (*From Dean and Taylor*)

	Middling Fair	Good Middling	Middling	Low Middling	Good Ordinary
Eastern Upland.....	8.63	8.75	10.66	12.23	15.64
Western Upland.....	8.22	9.35	11.47	13.37	16.89

TABLE XLVIII.—COMPARATIVE TENSILE STRENGTH OF 22's YARNS IN POUNDS PER SKEIN OF 120 YARDS (MILL TESTS) (*From Dean and Taylor*)

	Middling Fair	Good Middling	Middling	Low Middling	Good Ordinary
Eastern Upland.....	74.6	74.5	72.5	71.5	68.0
Western Upland.....	83.9	81.4	80.9	71.1	74.9

bleached under the same conditions, were practically identical in color. The goods from Middling were not so pure white as those from Middling Fair and Good Middling, but for commercial purposes the results were satisfactory. The goods from Low Middling appeared to have a slightly slaty color when closely compared with the other grades, while the goods made from Good Ordinary were easily distinguished by a slaty, bluish caste when compared with goods made from a higher grade.

As a conclusion of their results, Dean and Taylor<sup>2</sup> say:

The tests based on the Official Cotton Standards of the United States show that, after making allowances for the losses due to the cleaning processes, there is comparatively little difference between the grades above and those below Middling in the price paid by the manufacturer for each pound of the usable cotton obtained from bales of the different grades, but there is a difference in the intrinsic value per pound of the manufactured product. Accordingly, on the basis of quotations and values at the time of the tests, the inducement in the price paid to the farmer for the production of high-grade cotton was not commensurate with the greater value to the manufacturer of the product derived from such cotton.

**Waste, Tensile Strength, Bleaching and Dyeing Properties of Cottons Belonging to Different Grades of Upland Tinged and**

**Stained Cotton.**—Meadows and Blair<sup>3</sup> report results of tests made to determine the relative values of the following grades of cotton: Low Middling, Good Middling yellow-tinged, Middling yellow-tinged, Low Middling yellow-tinged, Good Middling yellow-stained, Middling yellow-stained, Good Middling blue-stained, and Middling blue-stained. The cotton was bought throughout the Cotton Belt by expert cotton classers connected with the Bureau of Markets, and in the tests was subjected to the same mechanical conditions.

The percentages of visible waste made by the different grades were as follows:

Grade	White	Yellow-tinged	Yellow-stained	Blue-stained
Good Middling.....	....	7.04	6.85	7.24
Middling.....	....	8.21	10.75	10.24
Low Middling.....	8.23	11.99		

From the above percentages of waste it seems that the waste follows the grade of cotton.

The Middling yellow-stained and Low Middling yellow-tinged gave off considerable fly. These grades were followed in order by Good Middling yellow-stained, Middling blue-stained, and Middling yellow-tinged. The other three grades gave off the usual amount of fly.

The breaking strength, in pounds per skein of 120 yards of 22's yarn spun from the different grades, was as follows:

Grade	White	Yellow-tinged, pounds	Yellow-stained, pounds	Blue-stained, pounds
Good Middling.....	....	85.7	87.2	76.6
Middling.....	....	88.5	82.9	79.5
Low Middling.....	81.3	81.2		

The results given above show that the highest grade did not always give the strongest yarn.

The bleaching and dyeing tests showed that Low Middling, Good Middling yellow-tinged, and Good Middling yellow-stained could be bleached satisfactorily for white yarns. The Middling yellow-tinged and Low Middling yellow-tinged when bleached

can be used for dyeing both light and dark shades. The Good Middling blue-stained and Middling blue-stained can be bleached satisfactorily for dyeing dark shades only.

The tensile-strength tests of single strands showed that the bleaching and dyeing processes did not materially affect the strength of the yarn, as shown by the average of all tests. The average strength of the gray yarn was 10.73 ounces; bleached, 11.05 ounces; pink, 10.83 ounces; blue, 10.60 ounces.

**Comparative Spinning Values of Certain Varieties of Long-staple Upland Cotton.**—Many spinners and cotton mill men have held to the belief that long-staple cotton grown in the Mississippi Delta was superior in spinning qualities to long-staple cotton grown on the Uplands of the eastern states. Experiments carried on by Taylor and Sherman of the U. S. Department of Agriculture to determine whether or not these views were well founded showed that Webber, Lewis, and Columbia when grown in the Southeast, were no more wasty than average Delta cottons, but that they had less strength. The three varieties just mentioned, however, were grown from well-bred seed, while the Delta cotton used was a mixture of five bales from different sources in the Delta and was all grown from unselected seed. This doubtless favored the eastern-grown varieties.

Table XLIX lists the varieties used in the tests made by Taylor and Sherman,<sup>4</sup> and gives their staple length, the grade of each used, and the breaking strength in pounds per skein of carded yarns and of combed yarns resulting from the 13 to 15 per cent comber settings.

TABLE XLIX.—STRENGTH OF CARDED AND COMBED YARNS

Variety	Grade	Staple	Carded yarn	Combed yarn
Durango.....	G. M.	1 <sup>3</sup> <sub>1</sub> 6	24.03	33.07
Columbia.....	S. G. M.	1 <sup>3</sup> <sub>1</sub> 6	25.56	34.50
Lewis.....	G. M.	1 <sup>5</sup> <sub>1</sub> 6	34.93	41.92
Webber No. I.....	M.	1 <sup>5</sup> <sub>1</sub> 6	25.88	32.12
Webber No. II.....	M.	1 <sup>5</sup> <sub>1</sub> 6	26.13	33.47
Delta.....	Blended grades	1 <sup>1</sup> <sub>4</sub>	32.98	42.05

R. W. Boys of the Farr Alpaca Mills, Holyoke, Mass., reports a waste of 18 to 20 per cent for carded cotton and 30 to 35 per

cent for combed. Strict Middling,  $1\frac{1}{8}$  inch full, Delfos cotton grown in the Mississippi Delta was used.

**Comparative Spinning Values of Certain Prominent Varieties with a Staple  $1\frac{1}{16}$  Inches in Length.**—Work carried on by Meadows and Blair<sup>5</sup> in 1922 gave evidence to the effect that several well-bred strains of  $1\frac{1}{16}$ -inch cotton possessed qualities that made them more attractive to spinners than cotton of that length from "North Georgia," a region with an established reputation for good cotton of such a length. The following summary by Meadows and Blair gives in brief the results from their experiment:

The cottons tested were from the crop of 1921, and consisted of the fiber of the following varieties: Acala, Lone Star, Mexican Big Boll, Rowden, and of typical cotton of the kind commercially known as "North Georgia." The Acala was grown in Alabama, the Lone Star, Mexican Big Boll, and Rowden were grown at different points in North Carolina, and the typical North Georgia cotton was grown in "North Georgia."

TABLE L.—GRADES, LENGTHS OF STAPLES, PERCENTAGE OF VISIBLE WASTE STRENGTHS OF THE YARN, AND PERCENTAGES OF AVERAGE DEVIATION OF THE SIZINGS AND STRENGTHS OF THE YARN

	Acala	Lone Star	Mexican Big Boll	Rowden	Typical "North Georgia"
Grade.....	Mid.	S. M.	G. M.	G. M.	S. M.
Length of staple, inches.....	$1\frac{1}{16}$	$1\frac{1}{16}$	1 full	$1\frac{1}{16}$	$1\frac{1}{16}$
Percentage of visible waste..	8.28	7.54	6.71	5.97	6.29
Strength of yarn, in pounds per skein of 120 yards:					
28's.....	70.5	62.3	67.2	63.5	56.4
36's.....	49.9	44.4	47.3	43.7	40.1
44's.....	38.2	33.5	34.4	33.9	25.6
Percentage of average deviation or irregularity of sizing of the yarn:					
28's.....	2.02	2.02	2.11	2.01	1.94
36's.....	2.06	2.06	2.18	1.79	2.10
44's.....	2.40	1.87	2.16	2.17	1.81
Percentage of average deviation or irregularity of strength of the yarn:					
28's.....	4.54	3.72	4.72	4.72	3.74
36's.....	4.51	3.86	5.09	3.98	3.86
44's.....	4.58	5.30	5.27	5.70	6.29



three cottons, Sea Island, Egyptian, and Arizona-Egyptian, was slight. On the whole, Egyptian Sakellaridis averaged slightly stronger, but Sea Island excelled in strength of fine yarns.

In respect to the bleaching and dyeing properties of the cottons under investigation, Taylor and Dean<sup>6</sup> say:

The laboratory test indicated that, after bleaching, dyeing, and mercerizing, the Arizona-Egyptian and the Sea Island cottons were practically equal to each other and were slightly superior to the Sakellaridis in their bleaching and mercerizing properties; that they were fully equal to

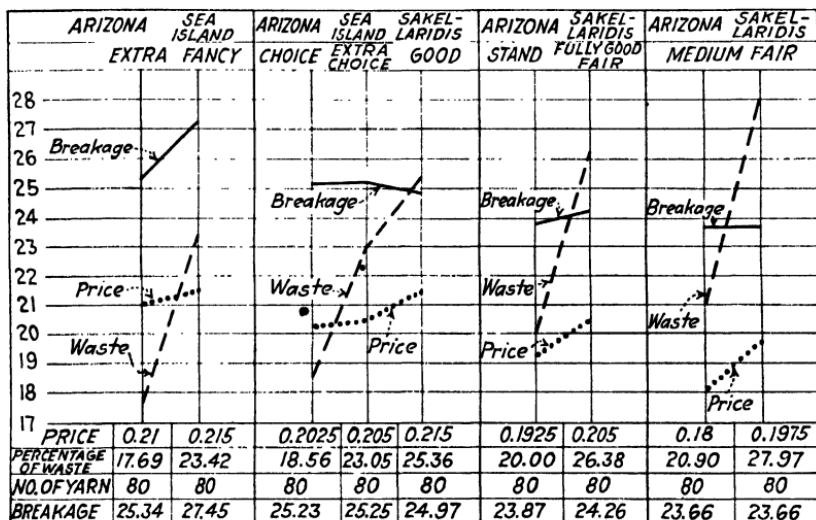


FIG. 126.—Comparison of the prices of raw cotton, waste discarded in the manufacturing processes, and the tensile strength of the yarn in pounds per skein of 120 yards each for Arizona-Egyptian, Sea Island, and Sakellaridis Egyptian cottons. (The figures at the left indicate the cents per pound for the price, percentage for the waste, and pounds per skein for the breaking strength.) (After Taylor and Dean.)

each other in dyeing properties; and in tensile strength the advantage was slightly in favor of the Sea Island and Sakellaridis. The finished gray and mercerized yarns were comparatively equal in luster; however, the yellow color was a little more evident in the Arizona-Egyptian than in the Sakellaridis, which, in turn, was somewhat more yellow than the Sea Island. The difference in color was more apparent between the Arizona and the Sakellaridis than between the Sea Island and Sakellaridis.

Figure 126 from Taylor and Dean<sup>6</sup> shows graphically the comparative prices of the three kinds of cotton mentioned above,

percentages of waste discarded in the manufacturing process, and the tensile strength of the yarn made from them. Equivalent grades are placed side by side. The figures on the left-hand margin indicate cents per pound for the price, percentage for the waste, and pounds per skein for the breaking strength. Number 80's yarn was used in the comparison.

Tests made by Meadows and Blair<sup>7</sup> on the comparative spinning values of Meade and Sea Island cottons showed that, on an average of results from three seasons, the Meade cotton was 3.5 per cent more wasteful than Sea Island. In the 3-year average, Sea Island showed a breaking strength 17.2 pounds greater than Meade when 23's yarns were compared and 1.68 pounds greater when 100's were compared. The grades used were almost the same, and the staple length used was all  $1\frac{5}{8}$ , except one lot of  $1\frac{7}{16}$  Meade.

**Effect of Bale Compression on Spinning Qualities.**—Much of the cotton fiber used in making cloth is compressed to make high-density bales before it is used, in order to economize space in box cars, warehouses, etc. The question often arises as to whether or not the extra compression that the lint in the bales receives reduces its spinning value.

Spinning tests were made by Meadows and Blair<sup>7</sup> to secure information on the question just mentioned. Cotton from Cleveland, Rowden, Delta, and Webber-49 varieties was used as examples of the different types of cotton with staples respectively of  $1\frac{5}{16}$ , 1,  $1\frac{1}{8}$ , and  $1\frac{1}{4}$  inches. Lint was taken from the regular uncompressed, or flat bale, as it is called; from standard or railroad compressed bales with a density ranging from 22 to 28 pounds per cubic foot; from high-density bales, the density ranging from 28 to 40 pounds per cubic foot; from high-density bales that were wet when compressed (from two of the varieties); and from a round bale (for one variety).

All of the tests made showed that compressing cotton to standard or high density when dry is not injurious to its spinning value, but compressing it to high density when wet may increase the percentage of waste, or it may decrease the strength of the yarn, or it may both decrease the strength and increase waste. It was found that compressing cotton into a round bale with a hard core reduced the strength of yarn about 7 per cent.

**Effect of Fumigation with Hydrocyanic Acid Gas on the Spinning Qualities of Cotton.**—Spinning and dyeing experiments

were carried on by Dean<sup>8</sup> with Egyptian, Peruvian, and Chinese cottons that had been subjected to the fumes of hydrocyanic acid gas. Some of the samples were subjected to the gas for 30 minutes to an hour from one to five times. The volume of gas that penetrated some of the bales was ten times as great as is ordinarily used in fumigating cotton.

As a result of the tests, Dean<sup>8</sup> says:

These tests indicate that the fumigation of cotton with hydrocyanic acid gas does not affect, to any material extent, the percentage of waste, spinning qualities, tensile strength, bleaching, dyeing, or mercerizing properties of the cotton.

**Special Value of Egyptian and Peruvian Cottons to American Spinner.**—Although America exports annually several million bales of cotton, there is imported each year from a quarter to half a million bales. The imported cottons are chiefly Egyptian and Peruvian cottons and inferior cottons from China and India.

The Egyptian cotton is especially good for making sewing thread, fine underwear, hosiery, etc., and for goods requiring a smooth finish or a high luster. Since it has a good luster, it is used to mix with silk in the manufacture of certain silk goods. It is also used extensively in the manufacture of mercerized goods.

Much of the Peruvian cotton imported into this country is the "rough Peruvian," a cotton with a stiff rough fiber that resembles wool. This cotton is used by manufacturers of woolen goods to mix with wool in making mixed or shoddy woolen goods, underwear, hosiery, etc. None of the American cottons are so well suited to this purpose.

**Utilization of Cotton Waste from Spinning Mills.**—Cotton waste from spinning mills consists principally of short fibers that have been rejected by machines in the process of combing and carding; and also floor sweepings, odds and ends from weaving, and various scraps.

According to the estimate by Lomax,<sup>10</sup> 25 per cent of the raw cotton that enters spinning and weaving mills in England is resold in the form of cotton waste as a by-product. This gives some idea of the quantity of waste produced in cotton mills.

The better grades of waste are used in making quilts, bed covers, domestic, sheets, towels, and flannelettes. The flat cylinder strips made in the process of carding are frequently used as raw material for products where strength is required, such as

for warps, twine, ropes, and nets. Large quantities of strips from Egyptian cotton are mixed with wool, on account of the strength of their fibers, and used in making mixed woolen goods. Lower qualities of waste are used in making sponge cloth, carpet yarns, and low-quality mixed woolen goods. Floor sweepings and fibers unfit for spinning are bleached and used in making gun cotton, cellulose, and artificial silk. Thready material that cannot be broken up or spun again is made into cleaning waste for engines and machines.

**Use of Linters.**—Cotton linters have a variety of uses other than for spinning purposes. The reader is referred to Chap. VII for further discussion. In cotton mills, linters are mixed with lamb's wool in making fleece-lined underwear, and are used in making low-grade yarns for lamp wicks and candle wicks, twine, carpets, and rope.

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## CHAPTER XXIV

### MAKING COTTON CLOTH

It does not fall within the province of this text to treat in detail the many phases of the cotton manufacturing industry. That is a large subject within itself, and the student seeking details may find special works on the subject, or on its different phases which will give him the desired information. The aim here is to trace cotton from the field to its finished product, and consequently the discussion will not be complete unless some mention is made of spinning, weaving, and other manufacturing processes. Information on these subjects should be of some interest and value to cotton growers, many of whom have never been inside a cotton mill and have but a vague notion of what takes place within its walls.

**History of Cotton Manufacturing.**—When the cotton fiber was first used in making cotton cloth is not definitely known, although it is certain that it was used in India prior to the Christian era. At that early date a primitive distaff was used in spinning, and the loom was little more than a few sticks or reeds. Many centuries elapsed before the cotton plant or cotton manufactures were introduced in Europe. According to Handy,<sup>1</sup> the first authentic record of the making of cotton cloth in England was in 1641. The industry grew slowly. Raw material was scarce, and the machinery used in spinning and weaving was crude. Because of the influence of people interested in the wool industry or the manufacture of woolen goods, laws were passed prohibiting the wearing of cotton goods and a fine was imposed on anyone who should weave or sell a piece of calico. This action of course, retarded the advancement of the cotton-weaving industry in England, but could not keep it down. Spinning and weaving were at first done in the home, and the worker got the idea that if improved machinery, which turned out a greater amount of goods, was introduced, not so many people would be needed to make the required amount of goods, and that some people would be deprived of work. Consequently, the workers were

opposed to new inventions and did everything possible to prevent their introduction. But several of the inventors worked with the spirit of martyrs. Gradually, the machines were improved until they became real mechanical wonders. It is almost beyond belief that machines, with almost no assistance by man, can take the tangled mass of cotton fibers and produce the fine, evenly woven cotton fabrics.

Until the latter part of the eighteenth century spinning was done with the distaff or spinning wheel, and the weaving on hand looms. In America, these machines were in use in homes all over the country prior to the Revolutionary War, and in the southern states they were used considerably later—even after cotton mills were well established. The women and children did the spinning and weaving. A generation or so ago spinning wheels were frequently seen stored in the attic of houses in America. The writer remembers having seen, when a boy, one that his grandmother had.

**Inventions in England.**—England early took an active interest in the textile industry. Being a commercial country, merchants found sale for much cotton goods and a heavy demand was created, greater, in fact, than could be met easily with the equipment at hand. “Necessity is the mother of invention.” The heavy demand stimulated inventors to endeavor to devise machines that would turn out goods more rapidly. As a result several important inventions were made.

The first in this series was the fly shuttle invented by Kay in 1738. Prior to his invention, the shuttle was thrown back and forth across the loom by hand. The new contrivance moved it back and forth by mechanical means and more rapidly. This invention improved the efficiency of the loom greatly, but it brought the inventor no reward. In fact, it brought him into disfavor, and weavers even threatened his life. Manufacturers made use of his invention, but refused to remunerate him and he died in poverty.

The success of the loom improvement just mentioned induced others of inventive mind to study spinning machines and led to the invention of Hargreaves’ “spinning jenny” in 1767. The first spinning jenny made contained eight spindles, but the number was later increased to eighty. This was a big improvement over the one spindle of the former spinning wheel. Its use alarmed neighboring spinners, who broke into Hargreave’s

house and destroyed his machine. He later rebuilt the machine and had it patented, but never succeeded in getting just returns from his invention. He died in comparative poverty.

Arkwright in 1767 improved the rollers for drawing out cotton strands, or sliver, in the spinning operation. The idea was originated by Wyatt about 1730, but it was not put into successful operation. Arkwright was more successful in a business way than the previous inventors mentioned. He amassed a fortune, and in 1786 was knighted by King George III.

Compton in 1779 made an improved spinning machine that would spin fine yarns. This was known as the "mule" spinning jenny, so called because it was a sort of cross between Arkwright's machine and Hargreaves' jenny. This machine brought cotton-spinning machinery to a high state of perfection. The next marked improvement in textile machinery was the invention of a power loom by Cartwright in 1785-1787.

**Cotton Mills.**—With the development and improvement of power-driven machinery for spinning and weaving came other changes. When the work was done by hand, or with simple machines run by hand, it was done in the home. But with the invention of power machinery it was moved to factories. These were small at first of course, but were the beginning of our modern factories. The first mills were located on streams where the advantage of water power could be secured.

The first cotton mill in the United States was erected at Beverly Mass., in 1787. Several others were established within the next few years, but progress was slow for several years. With the invention of Whitney's cotton gin in 1793, Lowell's power loom in 1814, and the ring spindle in 1830 came considerable improvement.

TABLE LI.—INCREASE IN COTTON SPINDLES IN THE UNITED STATES

Year	Number spindles	Year	Number spindles
1805	4,500	1860	5,200,000
1810	87,000	1870	7,100,000
1820	220,000	1880	10,700,000
1825	820,000	1890	14,200,000
1831	1,200,000	1900	19,000,000
1840	2,300,000	1910	28,500,000
1850	3,600,000	1920	34,500,000

From Table LI it may be seen that there was a rather steady increase in the number of cotton spindles in the United States during the first hundred years of the cotton-manufacturing industry. The New England states first took the lead in the industry, Providence, Fall River, New Bedford, and Lowell being important centers. But since 1860 the southern states have been gaining rapidly in comparative number of spindles. In 1891, the northern states had 12,900,000 spindles and the southern states had 1,740,000. In 1923 the northern states had 20,946,538 spindles and the southern 16,483,657. Copeland<sup>2</sup> considers that this phenomenal increase of mills in the South is due to four causes, namely, proximity to source of raw material, water power, lower taxation, and cheaper labor.

The increase in cotton mills in the South has had an effect on social and industrial conditions there. The increase in factories brings an increase in wealth, more taxes, more money for public improvements, schools, etc., and higher standards of social life are possible.

**Cotton Mills in Foreign Countries.**—England has long been the leader in the manufacture of cotton goods and is still in the lead, but her margin is decreasing, as may be seen from Table LII. More than 90 per cent of her spindles are in the one county of Lancashire. France and Germany also have extensive cotton mills. The relative rank in spindlage of several countries of the world is shown by Table LII.

TABLE LII.—COTTON SPINDLES OF THE WORLD

	1920	1907
United States, North.....	19,600,000	16,850,000
United States, South.....	15,100,000	9,500,00
Great Britain.....	57,300,000	50,700,000
Germany.....	9,400,000	9,300,000
France.....	9,400,000	6,800,000
Russia and Poland.....	8,000,000	8,100,000
India.....	6,700,000	5,300,000
Austria.....	5,000,000	3,600,000
Italy.....	4,800,000	3,500,000
Japan.....	3,400,000	1,500,000
Spain.....	2,000,000	1,900,000
Brazil.....	1,600,000	800,000
Switzerland.....	1,500,000	1,400,000
Belgium.....	1,538,000	1,140,000
Other countries.....	5,975,000	4,730,000
Total.....	151,313,000	124,320,000

**How Cotton Cloth Is Made.**—To a person that has never seen a large cotton mill a trip through one is a most interesting experience. It is a revelation almost to see what the various machines can do. The theory of cloth manufacture and a brief description of the most important processes will now be given.

Cotton that is to be made into cloth must be thoroughly cleaned of foreign material; then it must be opened so that each fiber is well separated from every other fiber; then the fibers must be straightened so that they will lie parallel, and then be twisted together to make a yarn. Such, in general, are the steps in getting the cotton ready for the loom. The whole manufacturing process may be divided into five parts: (1) preparatory processes; (2) spinning; (3) spooling, warping, and sizing; (4) weaving; and (5) finishing.

The type of machine used varies, of course, to some extent in different mills, and the processes the cotton is put through vary, depending on the quality of goods to be made. In the following discussion a brief sketch will be given of the processes commonly used in making an ordinary type of goods.

**Preparatory Processes.**—Before spinning proper can begin, the raw cotton must pass through several machines—bale breaker, picker, carding, combing, and drawing machines.

*Bale Breaker.*—When bales of cotton are first opened in the cotton mill, the lint cotton is found to be in more or less compact masses or laps due to the pressure that has been applied to it in baling or compressing bales. These laps are passed into a bale breaker, which contains three pairs of rollers, two of them spiked and one fluted, which disentangle and spread apart the fibers to some extent and deliver a more fluffy mass of cotton. From the bale-breaker room, the cotton is usually blown through large pipes to the room in which the pickers are situated.

*The Picker.*—The purpose of the picker, or scutcher sometimes called, is to separate fibers from each other, or spread them apart so that they will appear to touch only in places, to remove bits of leaf, dirt, and other foreign matter, and to roll the cotton into a more or less regular layer or "lap."

The cotton is carried to the picker, or opener, by a movable lattice apron, from which it is taken up by two feed rollers (Fig. 127E). In the picker it is first subjected to the action of a beater (Fig. 127A), which consists of a large rapidly revolving roller with teeth over the surface. These teeth seize the cotton and

fling it about, a part being flung by centrifugal force against an iron grid (Fig. 127B), through which dirt and foreign matter falls. Other teeth seize the cotton again and whirl it about. It is sub-

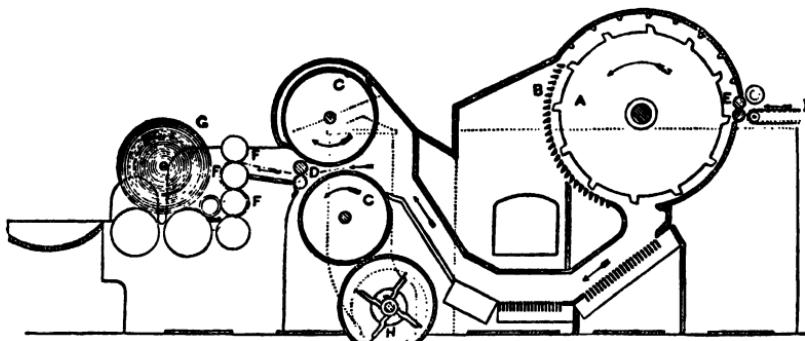


FIG. 127.—Cross-section diagram of picker.

sequently carried around an indefinite number of times and thrown against the grating until a large part of the dirt and

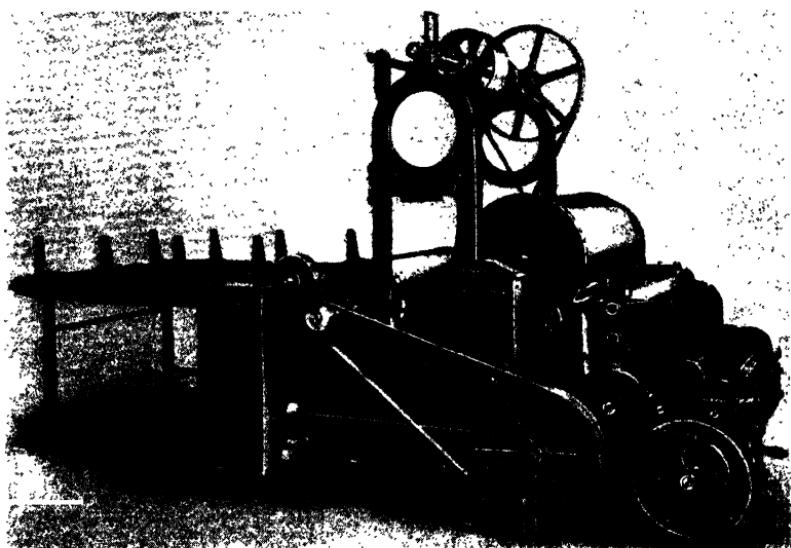


FIG. 128.—Picker or opener machine. (*Courtesy White Machine Company.*)

foreign matter is removed. The cotton gradually works its way along a channel in the lower part of the machine, as shown by the arrows in Fig. 127, and comes out between two large rollers

(Fig. 127C), which compress it into a sheet of batting. This sheet is rolled into a large roll (Fig. 127G), which may be 2 or 3 feet in diameter. The cotton is now ready for the first doubling or blending process. If the mill is interested in making very strong or even yarn, four sheets or laps from the picker are placed of top of one another and fed into another picker. This machine breaks up the laps, thoroughly mixes their fibers, takes out more foreign matter, and makes a more even lap. When the cotton comes from this picker, or scutcher, it is much whiter and cleaner looking than when first taken from the bale.

*The Carding Machine.*—When the cotton comes from the last picker, or finisher picker, the fibers are tangled and point in every

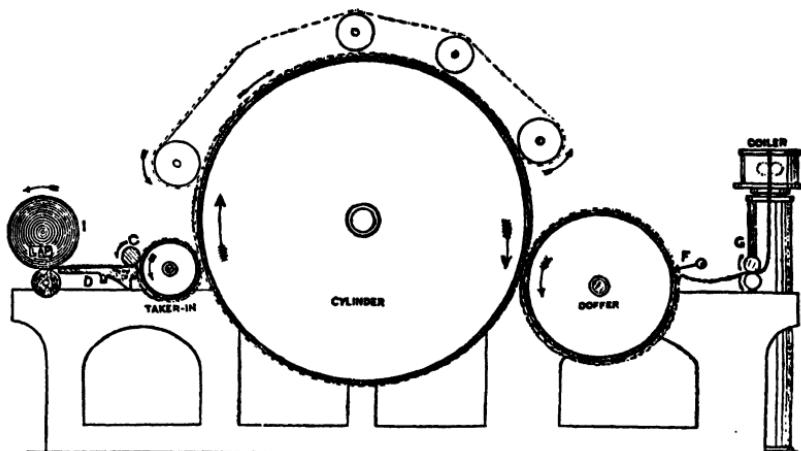


FIG. 129.—Cross-section diagram of revolving flat card.

direction just as they happened to be arranged as they come out. It is the function of the carding machine to place the fibers parallel, to remove remaining impurities and immature fibers, and to form the mature fibers into a porous rope or band called a sliver.

The fibers are straightened out and made to lie parallel by combing or brushing them with wire brushes or cards. In the revolving flat card, which is in common use at present, there are, as a rule, three principal cylinders. The lap passes first under the smallest of the three, called the taker-in, or licker, which is covered with very fine saw teeth all in one long strip of steel, wound and fixed spirally in the surface of the cylinder. The taker-in receives the cotton from a feed roller (Fig. 129C) that turns

above a smooth iron plate (Fig. 129D) called the feed plate. The saw teeth comb the fibers which are imbedded in the lap, remove some impurities, and deliver the loose fibers to the second cylinder, which is the largest of the group. This main cylinder is covered with wire teeth all bent at exactly the same angle. The cotton clings to them, and is carried around to the top of the cylinder, where it is engaged by teeth on the revolving flat card, which are bent in the opposite direction. This flat card, which is arranged on a traveling lattice, moves in the same direction as the large cylinder, but moves very slowly. This cards the fibers between

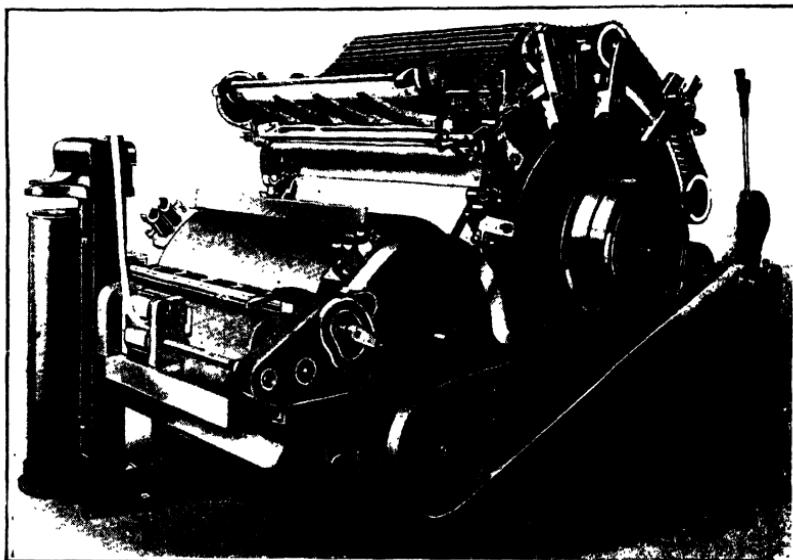


FIG. 130.—Carding machine. (*Courtesy Whiting Machine Company.*)

two sets of wire points. The short and immature fibers tend to remain on the card wires of the lattice, while the perfect fibers, which are now almost entirely parallel, are carried over on the main cylinder to the doffer cylinder, the third of the three cylinders mentioned above (Fig. 129). From this cylinder the fibers are removed by an oscillating comb (Fig. 129F), coming off in a light, fleecy lap, which is condensed through a funnel into a soft, untwisted roping, or sliver, about half an inch in diameter. The sliver is coiled and deposited in a deep, narrow can. These cans may be carried to other machines, and the sliver removed without getting it tangled or damaged.

**Combing.**—When very fine or very uniform yarns are sought, the cotton is subjected to the process of combing. This is an actual combing, as the name implies. The cotton is raked by a fine-tooth comb with needle-like steel teeth ranging from sixteen to ninety per inch. This process removes short fibers left in the cotton. The slivers from fourteen to twenty cans which are placed near together are drawn along side by side and passed between drawing rollers, which lengthen them and reduce their diameter. The slivers next pass between two pairs of calender

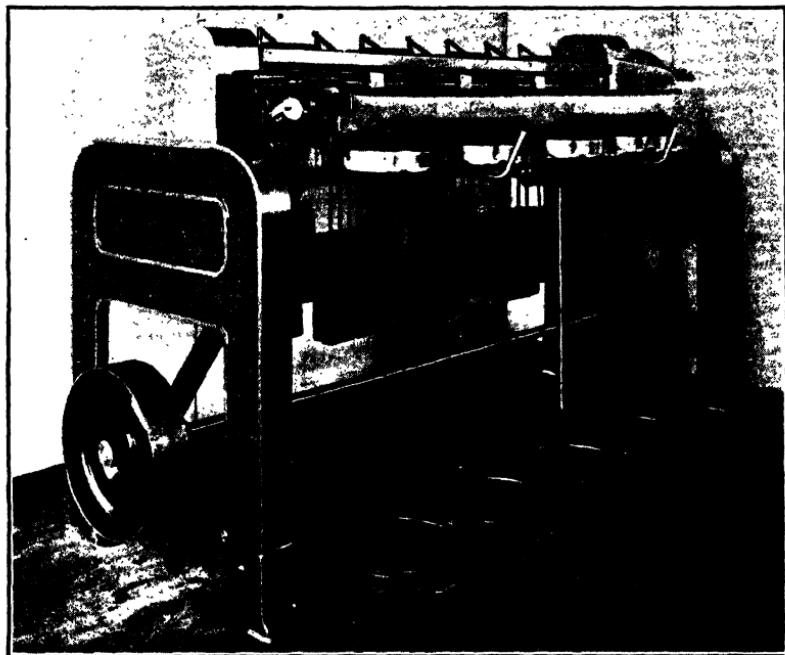


FIG. 131.—Drawing frame. (Courtesy Whitin Machine Company.)

rollers and emerge as a narrow lap. These laps are drawn and doubled by being superimposed one or more times, the number depending on the quality of yarn to be made. The lap then passes the combs, where it is raked and combined with other combed laps to make a sliver which is again deposited in a can.

**Drawing Frames.**—Slivers from the card or comber are next taken to the drawing frame (Fig. 131). The masses of fibers in the sliver are still irregularly distributed. It is the function of the drawing frame to eliminate irregularities in the sliver and make a smooth, uniform yarn. This is accomplished by doubling

or uniting laterally several slivers and then drawing them out to the dimension of one. For finer yarns, 216 or more doublings may be made.

The attenuation or drawing out of the sliver is effected by passing it between successive pairs of rollers, each succeeding pair revolving at a greater rate. The last pair in a series revolves six or eight times as rapidly as the first. This produces a constant pull on the roping of cotton and lengthens it.

From the drawing frame the sliver is taken to the slubbing frame, where it is attenuated, slightly twisted, and wound on spools. The sliver becomes the slubber roving, on being twisted.

The slubber roving is next passed to the intermediate frame, where it is doubled, drawn out to less diameter than the original roving, twisted, and wound on a spindle.

The next drawing frame or speeder, as it is called, receives the rovings from the intermediate frame, combines two of them into one, twists them a little more, and winds them on tubes. Still another speeder frame known as a jack frame is used for very fine yarns spun from Sea Island or Egyptian cotton.

**Spinning.**—In the spinning process the roving is further attenuated and twisted into a firm, coherent yarn of the required strength and fineness. There are two types of spinning machines in use, the "mule" and the "ring" spindle. The "mule," which was invented by Crompton, is the older type. About 75 per cent of the spindles in use in England are of this type. The ring spindle, which was invented by an American, James Thorpe, in 1828, is used in America almost altogether. It is claimed that the mule spindle will spin smoother and finer yarns, but the ring type is simpler and more rapid in its work.

The mule spinning machine is a large machine, carrying in some instances as many as 1,300 spindles. In this machine the drawing and twisting are intermittent. The rovings (Fig. 132B), which are held on a creel at the back of the machine, run from the spools through three pairs of rollers (Fig. 132C) to the spindles on the carriage. The carriage (Fig. 132) at intervals moves away from the creel and draws the rovings somewhat, since it moves slightly faster than the rovings are unwound. As the carriage recedes, the spindles, which are revolving rapidly, give twist to the yarn. Reaching the end of its course, which is about 63 inches, the carriage reverses and returns. The spindles reverse their course on the return trip of the carriage, and the yarn on

them in unwound and then rewound in the opposite direction on the spindles.

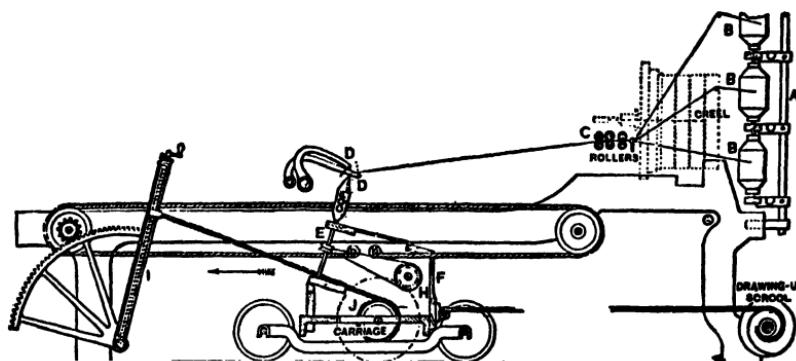


FIG. 132.—Diagram of mule spinning machine.

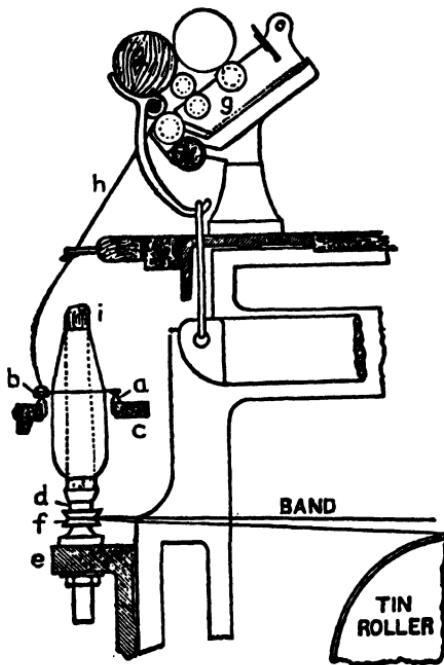


FIG. 133.—Diagram of ring spinning machine.

The "ring" spindle is more simple than the "mule" and has no movable carriage (Fig. 133). The roving (Fig. 133*H*)

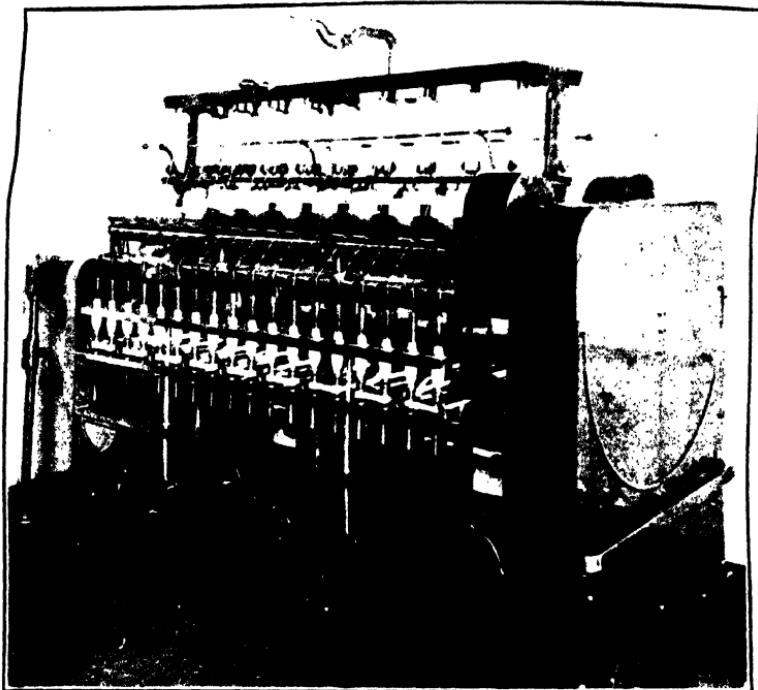


FIG. 134.—Ring spindles in operation. (Courtesy Whitin Machine Co.)

the rings are attached (Fig. 133C) moves up and down slowly, so that the yarn may be properly distributed over the spool on which it is wound. Figure 134 shows machine with ring spindles in operation.

**From Spinning Machines to Loom.**—The spinning machine leaves its yarn or finished product wound on a bobbin known as a cop. The cops that are used for weft in weaving, that is, the threads that run across the goods, are placed in shuttles and used in weaving without going through any further processes. The

yarn from cops that is to be used for warp, the threads that run the long way of the goods, must be wound on large spools before it can be warped. A simple machine known as a spooler is used in this work. The spool revolves at a rapid rate and the thread is wound on it evenly. The yarn used for warp is usually twisted a little more than the weft yarn.

The spools from the spooler are placed on a large frame called a creel (Fig. 135). The creels have an average capacity of about 600 spools. Threads from the spools are unwound to make the warping for the loom. When the threads leave the spools, they are drawn between the dents of an adjustable reed, and then

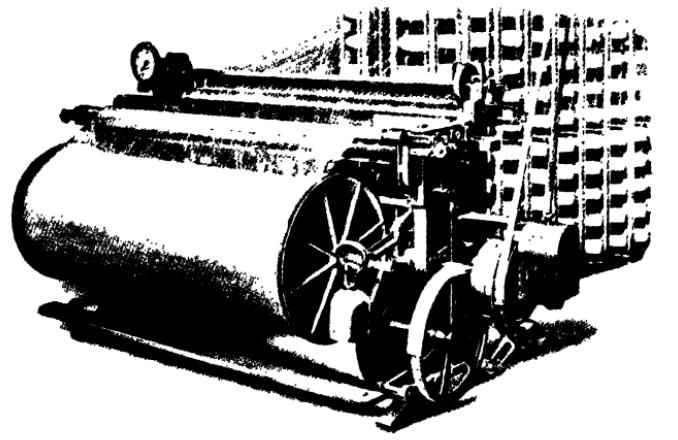


FIG. 135. Warping being wound on beam (the large roller). Creel containing numerous spools in the rear.

under and over a series of rollers. From here they are led down to the beam, upon which they are wound. The revolving of the beam unwinds the yarn from the spools and winds it regularly and evenly on the beam itself. There is a device for measuring the length of the warp wound, and a stop mechanism for arresting the operation should a thread break or an accident occur.

The yarn of the warp must usually be impregnated with a sizing which will smooth out and stick down its furry surface and also add to its tensile strength, so that the strain of weaving may be withstood. For the sizing process, a machine known as the "slasher" is most generally used. The chief feature of this is a roller whose lower side is immersed in the sizing solution.

Threads from the warp beam are run around this roller through the solution and then dried by passing them over a heated roller. The threads are next wound on another beam for the loom. More than one loom beam can be filled from the one set of warper beams mounted in the slasher. The warp is next taken to the loom.

**Weaving.**—In the process known as weaving, the warp and the weft are interlaced with each other as seen in woven goods. This work is done by a machine known as a loom (Fig. 136). The following are the principal steps in weaving:

1. Raising or lowering alternate threads of the warp so that the weft thread may be passed between them by means of the shuttle.



FIG. 136. Plain cotton loom.

2. Pushing each new thread of the weft into position against the preceding thread.

3. Unwinding the warp from its beam as fast as it is woven, and winding up the woven cloth.

**Finishing.**—When cotton goods leave the loom they are ready for the finishing operations. These include bleaching, printing, mercerizing, dyeing, starching, dampening, pressing, and other treatments.

**Bleaching.**—When a piece of cotton goods leaves the loom it is more or less soiled, it has some colored motes from leaf fragments and other foreign matter that were in the lint cotton; and it is colored somewhat by the natural yellowish or brownish

color of the lint cotton. The bleaching renders the goods a pure white, and if it is properly done the fabric is not injured.

In the bleaching process the goods are first boiled in plain water, which removes soluble material. They are next boiled in a strong alkaline solution to remove fatty and waxy substances in the fibers. Such substances interfere with bleaching and dyeing if left in the goods. Next the goods are steeped in a bleaching solution, chloride of lime being commonly used for this purpose. These chemicals must be neutralized and washed out thoroughly, or the goods will be damaged. In the first washing following the bleacher, a dilute solution of sulphuric acid is used. This is followed by another washing in which the water may be made slightly alkaline.

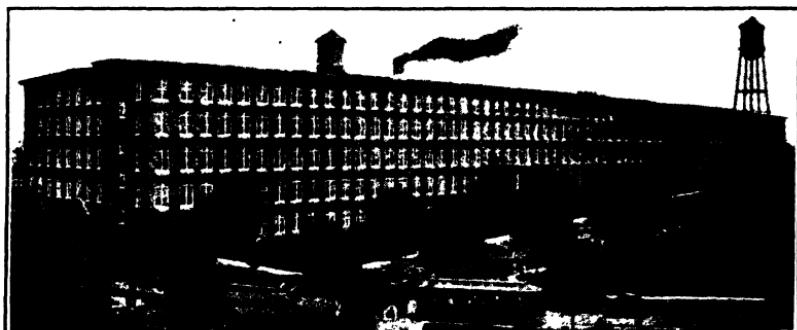


FIG. 137.—Woodside Cotton Mills, Greenville, S. C.

*Dyeing*.—In the dyeing process, the goods are passed through dyeing vats and washing tanks until the desired effect is obtained. Much skill is required in making up the dyeing solution in order that it may give a good even shade of the color desired.

*Mercerizing*.—The finishing process known as mercerizing was invented by John Mercer, an English calico printer, in 1844. Mercerized goods are characterized by a beautiful luster which makes them resemble silk. Either yarn, warp, skein, or goods may be mercerized by treating them with strong caustic soda solution or certain other reagents. With this treatment the goods are more attractive in appearance, stronger in fiber, and take dyes better. Principally long-staple cottons, especially Sea Island and Egyptian, are used for mercerizing.

*Printing*.—Certain goods, such as calicoes, are printed or stamped on one side with dyes of various colors, so as to give them

a figured appearance. The printing is done on a press, which has a large cylinder and smaller engraved rollers. Under each engraved roller is a long copper trough containing a particular coloring matter. Between the engraved roller and the trough of coloring matter and dipping into the latter is a second roller known as a furnisher, which transfers dye from the trough to the engraved roller. As the cloth moves by the different engraved rollers, each adds its particular color until the complete figure containing several colors is made.

The goods next pass into a drying room and are afterwards steamed under slight pressure. The steaming causes the colors to penetrate fibers more thoroughly. Better classes of goods are also washed to rid them of thickening matters mixed with the coloring.

There are many other details connected with the printing process, and there are other methods of making figured goods, but lack of space prevents further discussion.

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## CHAPTER XXV

### COTTON STATISTICS

Statistics on any subject are commonly considered to be dry reading matter. They are devoid of interest except to the person who wishes to use them in interpreting the trend of some industry.

There is considerable truth in the old saying that history repeats itself. By studying carefully figures on the cotton acreage, production, and resultant prices in different countries of the world for periods in the past, it is possible for a cotton grower, dealer, or manufacturer of cotton goods to work out certain laws which he may fit to his immediate conditions and thus be able to forecast, to some extent, the trend of future demand or future prices.

Accurate statistics furnish a convenient and reliable means of studying the history of the cotton industry in different countries and in different parts of the same country. It is only by means of statistical data that the industries of different countries can be compared.

The available statistics on various phases of the cotton industry are not very satisfactory. In the past, many countries had no regular or reliable system for collecting data. The figures given out were largely based on estimates. Even at present some of the large cotton-producing countries, China, for instance, have no good system for collecting data. The United States probably has the best system in use; yet it is open to some objections. Some of the figures are based on estimates, and in the past careful distinction was not made between gross and net weights of bales, and at times between crop year, calendar year, and fiscal year, and the weight of bales was not given.

The size of bale, or package of lint cotton, in use in different countries varies from 100 to 750 pounds. The weights of tare, bagging, and ties around the bale vary considerably in different countries. In some countries the cotton goods produced are measured by the pound, in others by the linear yard, and in still

others by the square yard. This lack of uniformity in different countries in methods of recording data makes comparison and study difficult.

**Statistical System in the United States.**—Since the United States has the most elaborate and probably the most satisfactory system for collecting cotton statistics and data on other crops, it may be well to discuss it briefly.

The Census Bureau of the Department of Commerce has local agents scattered over the cotton-growing states. These agents canvass the ginners twice a month during the ginning season and obtain figures on the actual number of bales ginned. They also visit cotton mills and other consuming establishments and obtain information on the amount of cotton and linters consumed, and of stocks held in consuming establishments, in compresses, and in public storage places. Statistics of exports, imports, and stocks held at ports are collected by the Bureau of Foreign and Domestic Commerce.

The Division of Crop and Livestock Estimates, Bureau of Agricultural Economics, U. S. Department of Agriculture, has a large corps of field agents and local crop reporters, who make estimates of acreage, crop condition, probable yield, etc. This force is grouped into five divisions:

1. Regional Cotton Statisticians.
2. State Agricultural Statisticians, each with a corps of helpers.
3. Township reporters.
4. Ginners.
5. Farmers and others interested in the cotton industry.

The cotton statisticians are men that are especially qualified for this work. They have had training in statistics and possess practical knowledge of crops. Each agent is assigned to a group of states, over which he travels systematically, rating acreage, noting general crop conditions, and consulting with the best-informed authorities. The cotton statisticians meet with the Crop Reporting Board when a report on cotton is to be issued.

In each of the cotton-growing states there is a State Agricultural Statistician, who is an employee of the government. He has qualifications similar to those of the Cotton Statisticians mentioned above. He spends much time traveling over the state studying crop conditions, acreage, etc. He has a large force of crop reporters, scattered over the state, who report to him. From these reports and from his own observations the State Agri-

cultural Statistician makes his report to the Bureau at Washington at regular periods.

There is also a large force of township and special reporters, who regularly make reports to the Bureau at Washington a short time before each government report. They report conditions in their immediate vicinity or in the local area with which they are familiar. These reporters are either farmers or men interested in and acquainted with local crop conditions.

There are still other reporters, mostly farmers and merchants, who make reports at irregular periods, or when called on.

The date and hour when each report shall be issued are fixed by law. These official reports are prepared and released by the Crop Reporting Board at Washington. The information from various sources is carefully guarded until the Board meets on the day of the report, when, behind locked doors, it is all brought together for the first time. The utmost precautions are taken to prevent any possibility of the premature release of any of the official report, owing to the effect it frequently has on the speculative market.

**Source of Information.**—The data given in the following tables are taken mostly from "Cotton Production and Distribution,"

TABLE LIII.—LENGTH OF COTTON LINT—RELATIVE PRODUCTION BY STATES

State	Per cent over 1 $\frac{1}{4}$ inches			Per cent 1 $\frac{1}{8}$ to 1 $\frac{1}{4}$ inches			Per cent short-staple		
	1918	1919	1920	1918	1919	1920	1918	1919	1920
Alabama.....	.....	.....	.....	0.7	0.3	0.1	99.3	99.7	99.9
Arkansas.....	2.6	3.4	3.1	20.4	15.4	18.6	77.0	81.2	78.3
Arizona.....	65.0	79.4	.....	3.6	.....	.....	35.7	35.0	20.6
California.....	.....	1.8	10.7	13.4	17.9	4.0	83.6	80.3	85.3
Florida.....	7.1	12.5	6.1	7.1	.....	11.1	32.2	87.5	82.5
Georgia.....	1.3	0.2	0.3	3.5	1.1	1.9	94.4	98.7	97.8
Louisiana.....	0.3	0.3	0.5	3.8	2.4	2.6	95.9	97.3	96.9
Mississippi.....	5.4	4.4	3.2	38.4	31.2	28.2	56.2	64.4	68.5
Missouri.....	.....	1.3	.....	6.5	5.6	6.4	93.5	94.4	92.3
North Carolina.....	0.1	0.1	0.2	0.9	1.4	1.1	99.0	98.5	98.7
Oklahoma.....	1.0	0.2	0.3	9.6	7.6	14.5	89.4	92.2	85.2
South Carolina.....	2.6	1.7	1.8	7.8	6.5	8.9	89.2	91.8	89.3
Tennessee.....	0.3	0.6	0.3	4.6	4.9	3.5	95.1	94.5	96.2
Texas.....	0.2	0.2	0.1	7.0	5.7	5.3	92.8	94.1	94.6
All others.....	.....	.....	.....	6.5	.....	.....	93.5	100.0	100.0
United States.....	1.5	1.3	1.5	9.8	7.5	8.3	88.1	91.2	90.2

Department of Commerce *Bulletin* 156. These data have been gathered largely by the United States government. Where data are taken from other authorities, the source is mentioned.

Table LIV shows the production of cotton, average net weight of bale, average value per pound, consumption of cotton and linters, exports of domestic cotton, and net imports of raw cotton from 1790 to 1924. The value of this table lies chiefly in its presentation for comparative purposes of relative quantities of each of the items shown for a series of years. The data here given cannot be used for arriving at the aggregate supply and distribution of cotton and linters for a number of years, or even for a single year, as the table does not take into account all items.

TABLE LIV.—PRODUCTION, CONSUMPTION, EXPORTS, AND NET IMPORTS OF RAW COTTON, FOR THE UNITED STATES, 1790 TO 1924

*Production.*—The production statistics relate, when possible, to the year of growth, but when figures for the growth year are wanting, those for a commercial crop which represents the trade movement have been taken. The statistics of production for the years 1790 to 1898, inclusive, have been compiled from publications of the Department of Agriculture; for the years 1899 to 1924, inclusive, and for other years, when available, census figures have been used.

*Price of Upland Cotton.*—For the years 1910 to 1924, inclusive, the price per pound shown for Upland cotton represents the average price received for cotton by the growers as computed by the Department of Agriculture; for the years 1902 to 1909 it is the average price of the average grade marketed in New Orleans prior to Apr. 1 of the following year; for the years 1890 to 1901, inclusive, it is the average price of middling cotton on the New Orleans Cotton Exchange; and for the years 1790 to 1889, inclusive, it is taken from reports of the Department of Agriculture.

*Consumption.*—The statistics of consumption for the years 1790 to 1894, inclusive, have been compiled from publications of the Department of Agriculture, and those for the years 1895 to 1903, inclusive, from the reports of Latham, Alexander & Co. Census figures have been used for the years 1904 to 1924, inclusive, and for other years when available. The statistics relate to the 12 months during which the crop of the specified year was chiefly marketed, and not to the calendar year specified.

*Domestic Exports and Net Imports.*—For the years 1790 to 1819, inclusive, the statistics have been taken from American State papers, and for the years 1820 to 1924 from the reports on Commerce and Navigation of the United States, published by the Bureau of Foreign and Domestic Commerce, Department of Commerce. For the years 1790 to 1842, inclusive, the statistics of exports relate to the 12 months beginning with Oct. 1 of the specified year; for 1843 to 1866, inclusive, to the 12 months beginning with July 1; for 1867 to 1913, inclusive, to the 12 months beginning with Sept. 1; and for 1914 to 1924 to the 12 months beginning with Aug. 1. The statistics of imports relate to the same periods as the statistics of exports.

TABLE LIV.—PRODUCTION, CONSUMPTION EXPORTS, AND NET IMPORTS OF RAW COTTON, FOR THE UNITED STATES, 1790 TO 1924

Year	Cotton production (including linters)				Consump- tion of cotton and linters (equivalent 500-pound bales) <sup>a</sup>	Exports of domestic cotton (equivalent 500-pound bales)	Net imports (equiva- lent 500- pound bales)
	Running bales, counting round as half bales	Equivalent 500-pound bales, gross weight	Aver- age net weight of bale, pounds	Aver- age price per pound Upland cotton, cents			
1924	14,497,361	14,487,560	478	22.9	6,877,617	8,434,978	303,443
1923	10,810,234	10,808,271	477	28.7	6,225,000	5,935,535	272,179
1922	10,319,843	10,369,848	480	22.9	7,350,000	5,049,225	449,783
1921	8,360,153	8,351,393	476	16.9	6,560,000	6,479,188	351,921
1920	13,699,975	13,879,916	484	15.8	5,477,908	6,025,915	210,606
1919	11,920,625	12,028,732	482	35.4	6,807,817	6,760,887	682,911
1918	12,816,716	12,970,048	484	28.8	6,288,922	5,843,307	197,201
1917	12,344,664	12,428,094	480	27.1	7,555,191	4,587,000	217,381
1916	12,664,078	12,780,644	482	17.3	7,721,354	5,963,682	288,486
1915	12,012,813	12,122,961	484	11.2	7,326,508	6,405,993	420,995
1914	16,738,241	16,991,830	485	7.3	6,087,338	8,931,253	363,595
1913	14,613,964	14,795,367	484	12.5	5,942,808	9,256,028	265,646
1912	14,090,863	14,313,015	486	11.5	5,867,431	9,199,093	225,460
1911	16,109,349	16,250,276	483	9.6	5,400,005	11,081,332	229,268
1910	11,965,962	12,005,688	480	14.0	4,713,126	8,025,901	231,191
1909	10,386,209	10,315,382	475	14.3	4,759,364	6,491,843	151,395
1908	13,432,131	13,587,306	484	9.2	5,198,963	8,889,724	165,451
1907	11,325,882	11,375,461	480	11.5	4,493,028	7,779,508	140,869
1906	13,305,265	13,595,498	489	10.0	4,974,199	8,825,236	202,733
1905	10,725,602	10,804,556	482	10.9	4,877,465	6,975,494	133,464
1904	13,697,310	13,697,954	478	8.7	4,523,208	9,057,397	130,182
1903	10,015,721	10,045,615	480	12.2	3,980,567	6,233,682	100,298
1902	10,784,473	10,827,168	481	8.2	4,187,076	6,913,506	149,113
1901	9,748,546	9,675,771	480	8.1	4,080,287	6,870,313	190,080
1900	10,245,602	10,266,527	480	9.3	3,603,516	6,806,572	116,610
1899	9,507,786	9,499,035	476	7.6	3,687,253	6,167,623	134,778
1898	11,189,205	11,435,368	489	4.9	3,672,007	7,626,525	103,223
1897	10,897,857	10,985,040	482	5.6	3,472,398	7,811,031	105,802
1896	8,532,705	8,515,640	477	7.3	2,841,394	6,124,026	114,712
1895	7,161,094	7,146,772	477	8.2	2,499,731	4,761,505	112,001
1894	9,901,251	10,025,534	484	5.9	2,983,665	6,961,372	99,399
1893	7,493,000	7,433,056	471	7.5	2,300,276	5,307,295	59,405
1892	6,700,365	6,658,313	475	8.4	2,415,875	4,485,251	85,735
1891	9,035,379	8,940,867	473	7.3	2,846,753	5,896,800	64,304
1890	8,652,597	8,562,089	473	8.6	2,604,491	5,850,219	45,580
1889	7,472,511	7,472,511	478	11.5	2,518,409	4,928,921	18,334
1888	6,938,290	6,923,775	477	10.7	2,300,250	4,730,192	15,284
1887	7,046,833	6,884,067	467	10.3	2,205,302	4,519,254	11,983
1886	6,505,087	6,314,561	464	10.3	2,049,687	4,301,542	7,552
1885	6,575,691	6,360,341	463	9.4	2,094,682	4,200,651	8,270
1884	5,682,000	5,477,448	460	10.5	1,687,108	3,783,319	7,144
1883	5,713,200	5,521,063	462	10.6	1,813,865	3,733,360	11,247
1882	6,949,756	6,833,442	470	10.6	2,038,400	4,591,331	4,716
1881	5,456,048	5,136,447	450	12.2	1,849,457	3,376,521	3,261
1880	6,605,750	6,356,998	460	11.3	1,865,922	4,453,495	5,447
1879	5,755,350	5,466,387	454	12.0	1,500,688	3,742,752	7,578
1878	5,074,155	4,745,078	447	10.8	1,457,266	3,290,167	5,049
1877	4,773,865	4,494,224	450	11.3	1,458,667	3,197,439	5,046
1876	4,474,009	4,118,390	440	11.7	1,314,489	2,839,418	4,832

<sup>a</sup> Data collected in running bales. Conversion based on average weights of bales produced, which for the country are heavier than those consumed.

TABLE LIV.—PRODUCTION, CONSUMPTION, EXPORTS, AND NET IMPORTS OF RAW COTTON, FOR THE UNITED STATES: 1790 TO 1924 (Continued)

Year	Cotton production (including linters)				Consump- tion of cotton and linters (equivalent 500-pound bales) <sup>a</sup>	Exports of domestic cotton (equivalent 500-pound bales)	Net imports (equiva- lent 500- pound bales)
	Running bales, counting round as half bales	Equivalent 500-pound bales, gross weight	Aver- age net weight of bale, pounds	Aver- age price per pound Upland cotton, cents			
1875	4,632,313	4,302,818	444	13.0	1,255,712	3,037,650	4,498
1874	3,832,991	3,528,276	440	15.0	1,098,163	2,504,118	3,784
1873	4,170,388	3,873,750	444	17.0	1,213,052	2,682,631	3,541
1872	3,930,508	3,650,832	444	18.2	1,115,091	2,470,590	10,016
1871	2,974,351	2,756,564	443	20.5	1,146,730	1,824,937	6,374
1870	4,352,317	4,024,527	442	17.0	1,026,583	2,922,757	1,802
1869	3,011,996 <sup>b</sup>	2,409,597	430	24.0	796,616	1,987,708	3,026
1868	2,366,467	2,198,141	444	29.0	860,481	1,300,449	1,870
1867	2,519,554	2,345,610	445	24.9	844,044	1,502,756	345
1866	2,097,254	1,948,077	444	31.6	715,258	1,401,697	1,035 <sup>b</sup>
1865	2,269,316	2,093,658	441	43.2	614,540	1,301,146	10,322
1864	300,000	299,372	477	83.4	344,278	17,789	68,798
1863	450,000	449,059	477	101.5	219,540	23,988	52,405
1862	1,000,000	1,596,653	477	67.2	287,397	22,770	67,695
1861	4,500,000	4,490,586	477	31.3	369,226	10,129	61,731
1860	3,849,469	3,841,416	477	13.0	841,975	615,032	
1859	5,387,052 <sup>b</sup>	4,309,642	461	11.0	845,410	3,535,373	
1858	4,018,914	3,758,273	447	12.1	867,489	2,772,937	
1857	3,257,339	3,012,016	442	12.2	550,708	2,237,248	
1856	3,093,737	2,873,680	444	13.5	761,614	2,096,565	1,678
1855	3,665,557	3,220,782	420	10.3	731,484	2,702,863	2,295
1854	2,982,634	2,708,082	434	10.4	641,391	2,016,849	4,425
1853	3,074,979	2,766,194	430	11.0	663,204	1,975,666	1,141
1852	3,416,214	3,130,338	438	11.0	736,468	2,223,141	1,423
1851	3,126,310	2,799,290	428	9.5	617,468	2,186,461	512
1850	2,454,442	2,136,083	416	12.1	422,626	1,854,474	330
1849	2,469,093 <sup>b</sup>	1,975,274	429	12.3	575,506	1,270,763	485
1848	2,866,938	2,615,031	436	7.5	586,032	2,053,204	22
1847	2,439,786	2,128,433	417	8.0	537,427	1,628,549	558
1846	1,778,651	1,603,763	431	11.2	385,916	1,054,440	122
1845	2,100,537	1,806,110	411	7.9	363,365	1,095,116	386
1844	2,394,503	2,078,910	415	5.6	337,730	1,745,812	680 <sup>b</sup>
1843	2,030,409	1,750,060	412	7.7	298,872	1,327,267	517
1842	2,378,875	2,035,481	409	7.2	278,196	1,584,594	1,835
1841	1,683,574	1,398,282	397	7.8	222,461	1,160,434	107
1840	1,634,954	1,347,640	394	9.5	245,045	1,060,408	1,210
1839	2,063,915	1,653,722	383	8.9	236,525	1,487,882	297
1838	1,360,532	1,092,980	384	13.4	221,738	827,248	319
1837	1,801,497	1,428,384	379	10.1	195,100	1,191,905	355
1836	1,423,930	1,129,016	379	13.2	176,449	888,423	510 <sup>b</sup>
1835	1,360,725	1,061,821	373	16.5	184,731	847,263	427
1834	1,253,406	962,343	367	17.4	166,523	774,718	1,574
1833	1,225,895	930,962	363	12.9	149,150	769,436	308
1832	1,114,286	815,900	350	12.3	142,352	649,397	69
1831	1,060,444	805,439	360	9.4	130,805	644,430	22 <sup>b</sup>

<sup>a</sup> Data collected in running bales. Conversion based on average weights of bales produced, which for the country are heavier than those consumed.

<sup>b</sup> Equivalent 400-pound bales.

<sup>c</sup> Excess of exports of foreign cotton over total imports.

TABLE LIV.—PRODUCTION, CONSUMPTION, EXPORTS, AND NET IMPORTS OF RAW COTTON, FOR THE UNITED STATES: 1790 TO 1924 (Continued)

Year	Cotton production (including linters)				Consump- tion of cotton and linters (equivalent 500-pound bales) <sup>a</sup>	Exports of domestic cotton (equivalent 500-pound bales)	Net imports (equiva- lent 500- pound bales)
	Running bales, counting round as half bales	Equivalent 500-pound bales, gross weight	Aver- age net weight of bale, pounds	Aver- age price per pound Upland cotton, cents			
1830	1,026,393	732,218	341	9.7	129,938	553,960	22
1829	1,076,696	763,598	339	10.0	89,723	596,918	378
1828	953,079	679,916	341	9.9	84,788	529,674	440
1827	805,970	564,854	335	10.3	84,516	421,181	597
1826	1,057,402	732,218	331	9.3	103,535	588,620	74
1825	817,308	533,473	312	12.2		409,071	79
1824	751,748	449,791	286	18.6		352,900	26
1823	656,029	387,029	282	14.7		286,739	932
1822	704,698	439,331	298	11.4		347,447	110
1821	636,042	376,569	283	14.3		289,350	196 <sup>b</sup>
1820	575,540	334,728	278	14.3	100,000	249,787	427
1819	632,576	349,372	264	17.0		255,720	4,571 <sup>b</sup>
1818	446,420	261,506	280	24.0		175,994	4,454 <sup>b</sup>
1817	465,950	271,967	279	34.0		184,942	3,086
1816	439,716	259,414	282	26.0		171,290	2,048
1815	369,004	209,205	271	29.0		163,894	44 <sup>b</sup>
1814	254,545	146,444	275	21.0	51,778	165,997	266 <sup>b</sup>
1813	304,878	156,904	246	15.5		35,458	101
1812	304,878	156,904	246	12.5		38,220	3,133
1811	325,203	167,364	246	10.5		57,775	897
1810	286,195	177,824	297	15.5	35,565	124,116	431
1809	328,000	171,548	250	16.0	33,473	186,523	560 <sup>a</sup>
1808	334,821	156,904	224	16.0		101,981	1,601 <sup>b</sup>
1807	280,855	167,364	276	19.0		21,261	6,297
1806	285,714	167,364	280	21.5		127,889	1,485
1805	304,348	146,444	230	22.0		71,315	961
1804	261,044	135,983	249	23.0	23,013	76,780	456
1803	222,222	125,523	270	20.0		70,068	183
1802	231,092	115,063	238	19.0		75,424	1,153 <sup>b</sup>
1801	210,526	100,418	228	19.0		47,768	170 <sup>b</sup>
1800	153,509	73,222	228	44.0	18,820	31,822	8,696
1799	88,880	41,841	225	28.0	16,737	35,580	8,870
1798	66,667	31,381	225	44.0		19,065	7,532
1797	48,880	23,013	225	39.0		18,720	7,761
1796	44,444	20,921	225	34.0		7,577	7,336
1795	35,556	16,736	225	36.5		12,213	8,737
1794	35,556	10,736	225	36.5		9,414	8,502
1793	22,222	10,460	225	33.0		3,565	5,127
1792	13,333	6,276	225	32.0		1,097	5,503
1791	8,880	4,184	225	29.0		277	1,112
1790	6,667	3,138	225	26.0	11,000	279	697

<sup>a</sup> Data collected in running bales. Conversion based on average weights of bales produced, which for the country are heavier than those consumed.

<sup>b</sup> Equivalent 400-pound bales.

## COTTON

TABLE LV.—COTTON ACREAGE HARVESTED, AND PRODUCTION, BY STATES, FOR SELECTED YEARS, 1839 TO 1925

(Quantities are given in running bales, except that round bales are counted as half bales. Linters are excluded. Census statistics of acreage prior to 1879 are not available. The statistics of acreage and of production for the census years 1879, 1889, and 1909, and those of production since 1898, are census figures based on actual canvass, while the others are as estimated by the U. S. Department of Agriculture.)

Growth year	United States	Alabama	Arkansas	Florida	Georgia	Louisiana	Mississippi	Missouri	North Carolina	Okla-homa	South Carolina	Tennes-see	Texas	Vir-ginia
1925—Acre <sup>b</sup>	46,448,000	3,425,000	3,649,000	115,000	3,564,000	1,916,000	3,424,000	1,013,000	2,183,000	4,867,000	2,740,000	1,219,000	18,237,000	96,000
1924—Acre <sup>b</sup>	40,000	3,190,000	3,058,000	111,000	3,767,000	1,537,000	3,256,000	934,000	522,000	3,672,000	2,188,000	1,144,000	15,595,000	92,000
1923—Acre <sup>b</sup>	37,122,000	3,079,000	3,026,000	147,000	3,21,000	1,465,000	3,107,000	637,000	679,000	3,197,000	1,965,000	1,007,000	14,740,000	91,982
Bales	10,170,594	598,140	643,343	13,628	612,812	373,812	622,617	292,345	1,053,402	665,904	789,817	235,344	4,212,248	51,982
1922—Acre <sup>b</sup>	33,038,000	2,771,000	2,799,000	118,000	3,418,000	1,140,000	3,014,000	410,000	1,625,000	2,915,000	1,912,000	985,000	11,874,000	55,000
Bales	9,729,306	819,870	701,010	520	735,874	345,407	985,757	222,030	879,294	637,063	517,464	335,860	3,125,758	27,011
1921—Acre <sup>b</sup>	30,509,000	2,235,000	2,382,000	65,000	4,172,000	1,168,000	2,628,000	296,000	1,403,000	2,906,000	2,577,000	634,000	10,445,000	34,000
Bales	7,977,775	587,669	788,047	12,262	892,621	284,330	816,861	154,617	803,620	477,777	786,039	297,555	2,129,660	16,680
1920—Acre <sup>b</sup>	35,878,000	2,958,000	2,980,000	100,000	4,900,000	1,470,000	2,980,000	540,000	1,587,000	2,749,000	2,149,000	840,000	18,888,000	42,000
Bales	13,270,970	670,330	1,182,010	19,443	1,447,159	389,569	900,371	272,709	949,484	1,302,610	1,652,177	314,811	4,148,399	21,898
1919—Acre <sup>b</sup>	33,566,000	2,791,000	2,725,000	103,000	5,220,000	1,527,000	2,848,000	327,000	1,490,000	2,424,000	2,835,000	758,000	10,476,000	42,000
Bales	11,325,532	716,655	807,177	17,317	1,678,758	303,035	950,807	185,156	857,253	1,032,178	1,462,277	301,408	2,860,335	32,076
1918—Acre <sup>b</sup>	36,700,000	2,570,000	2,991,000	167,000	5,341,000	1,883,000	3,138,000	340,000	1,600,000	2,303,000	3,007,000	623,000	11,233,000	44,000
Bales	11,906,440	788,265	897,118	34,851	2,117,860	682,698	1,183,122	191,719	585,149	1,149,151	1,581,726	317,962	2,610,337	25,235
1917—Acre <sup>b</sup>	33,841,000	1,977,000	2,740,000	183,000	5,195,000	1,454,000	2,788,000	345,000	1,515,000	2,783,000	2,827,000	882,000	11,092,000	50,000
Bales	11,248,242	520,906	933,587	48,178	1,885,054	629,719	886,266	144,709	656,656	955,342	1,267,135	258,866	3,641,726	20,155
1916—Acre <sup>b</sup>	34,985,000	3,235,000	2,600,000	191,000	5,277,000	1,256,000	3,110,000	210,000	1,451,000	2,562,000	2,786,000	887,000	11,400,000	42,000
Bales	11,463,915	552,679	1,102,671	50,579	1,852,104	441,121	800,190	117,550	733,672	813,419	970,702	378,064	3,562,788	27,975
1915—Acre <sup>b</sup>	31,412,000	3,340,000	2,170,000	183,000	4,825,000	990,000	2,735,000	150,000	1,282,000	1,895,000	2,516,000	772,000	10,510,000	34,000
Bales	11,068,173,025	818,799	583,554	1,937,730	336,813	955,409	82,192	737,354	622,176	1,174,213	206,222	3,068	852,16,357	
1914—Acre <sup>b</sup>	36,832,000	4,007,000	2,480,000	221,000	5,433,000	1,298,000	3,054,000	212,000	1,527,000	2,847,000	2,861,000	1,065,000	11,831,000	45,000
Bales	15,905,840	1,731,751	990,237	90,648	2,123,084	455,261	1,917,883	140,109	701,479	1,237,688	1,366,195	372,068	4,380,200	25,277
1913—Acre <sup>b</sup>	37,098,000	3,760,000	3,502,000	188,000	5,318,000	1,244,000	3,067,000	126,000	1,576,000	3,009,000	2,790,000	865,000	12,597,000	47,000
Bales	13,488,811	1,483,669	1,038,293	66,700	2,346,237	436,865	2,511,841	95,629	837,985	2,482,498	1,418,704	366,786	3,773,024	569
1912—Acre <sup>b</sup>	34,288,000	3,730,000	3,911,000	224,000	5,335,000	929,000	2,889,000	112,000	1,545,000	2,665,000	2,920,000	783,000	11,338,000	47,000
Bales	13,488,539	1,328,297	770,937	58,833	1,812,775	374,793	1,004,376	64,573	906,351	1,005,109	1,224,245	267,439	4,645,369	25,499

1911—Acres.....	36,045,000	4,017,000	2,363,000	308,000	5,504,000	1,075,000	3,340,000	141,000	1,624,000	3,050,000	2,800,000	837,000	10,943,000	43,000		
Bales.....	15,453,073	1,655,284	908,014	94,471	2,734,295	380,826	1,169,066	10,879	1,226,726	1,016,538	1,692,146	430,057	4,107,152	31,089		
1910—Acres.....	32,403,000	4,000	2,238,000	265,000	4,878,000	1,550,000	3,317,000	108,000	2,040,000	2,534,000	765,000	10,060,000	30,000	10,060,000	33,000	
Bales.....	11,568,334	1,192,179	798,156	67,172	1,812,178	246,788	1,212,104	68,694	753,087	919,842	1,210,968	321,103	2,949	948	16,095	
1909—Acres.....	32,044,000	3,731,000	2,153,000	263,000	4,983,000	957,000	3,400,000	106,000	1,274,000	1,977,000	2,557,000	788,000	9,920,000	25,000		
Bales.....	10,072,731	1,040,137	697,603	61,877	1,860,125	254,459	1,073,165	46,785	633,746	952,678	1,197,382	240,777	2,469,331	10,746		
1905—Acres.....	32,444,000	3,590,000	2,296,000	265,000	4,848,000	1,550,000	3,317,000	87,000	2,040,000	2,534,000	754,000	9,316,000	28,000	9,316,000	28,000	
Bales.....	13,086,005	1,332,003	996,093	70,598	1,977,050	466,543	1,620,325	60,025	633,628	689,345	1,215,848	334,034	3,627,350	13,113		
1907—Acres.....	29,660,000	3,148,000	1,902,000	209,000	4,566,000	1,540,000	3,081,000	63,000	1,408,000	2,485,000	693,000	8,478,000	23,000	8,478,000	23,000	
Bales.....	11,657,822	1,113,003	751,931	56,868	1,860,323	662,032	1,442,861	36,415	627,961	948,977	1,183,565	266,432	2,268,021	9,602		
1906—Acres.....	31,374,000	3,638,000	2,067,000	263,000	4,701,000	1,739,000	3,480,000	91,000	1,314,000	1,981,000	589,000	814,000	584,000	584,000	36,000	
Bales.....	12,983,201	1,241,133	894,268	61,748	1,632,703	955,473	1,483,400	55,884	611,258	871,961	1,912,602	293,023	3,957,619	14,596		
1905—Acres.....	27,110,000	3,425,000	1,723,000	230,000	4,020,000	1,445,000	3,019,000	70,000	1,230,000	2,340,000	629,000	7,432,000	38,000	7,432,000	38,000	
Bales.....	10,195,105	1,225,000	598,915	78,588	1,725,272	511,738	1,168,059	41,664	812,854	660,027	1,112,363	269,030	2,432,718	15,686		
1904—Acres.....	31,251,000	3,804,000	2,173,000	272,000	4,397,000	1,967,000	3,911,000	92,000	1,409,000	1,553,000	566,000	780,000	2,233,000	38,000	2,233,000	38,000
Bales.....	13,451,337	1,451,362	901,223	87,525	1,962,890	1,048,683	1,774,464	51,434	749,412	796,382	1,192,926	320,317	3,062,302	11,216		
1903—Acres.....	27,052,000	2,931,000	1,796,000	178,000	3,834,000	1,772,000	3,250,000	78,000	1,201,000	981,000	2,112,000	597,000	8,287,000	35,000		
Bales.....	9,819,969	967,224	715,588	58,572	1,305,844	818,087	1,410,805	36,839	555,320	546,704	814,351	240,600	1,461,153	681		
1902—Acres.....	27,075,960	3,178,000	1,735,000	237,000	4,129,000	1,413,000	3,141,000	58,000	1,111,000	1,022,000	2,211,000	604,000	8,096,000	30,000		
Bales.....	10,568,250	965,518	949,101	67,287	1,475,834	866,911	1,423,385	42,289	567,530	530,709	948,005	201,102	2,427,984	16,575		
1901—Acres.....	26,774,000	3,377,000	1,988,000	206,000	3,782,000	1,541,000	2,928,000	76,000	1,395,000	880,000	2,341,000	694,000	7,545,000	35,000		
Bales.....	9,682,520	1,112,892	712,492	57,144	1,373,857	834,048	1,232,728	29,951	1,228,128	371,029	731,561	2,447,834	14,009			
1900—Acres.....	26,933,000	3,244,000	1,766,000	342,000	4,129,000	1,413,000	3,150,000	49,000	1,143,000	574,000	2,140,000	600,000	7,298,000	29,000		
Bales.....	10,402,102	1,028,640	801,084	55,696	1,236,901	703,061	1,637,029	27,130	568,302	346,237	779,849	215,275	3,329,015	11,833		
1899—Acres.....	24,275,101	3,202,135	1,641,855	221,825	3,513,839	1,376,254	2,887,920	48,201	1,007,020	682,743	2,074,081	623,187	6,980,387	25,724		
Bales.....	9,393,242	1,046,667	702,512	56,821	1,297,386	701,662	1,239,373	19,582	472,770	209,611	874,744	2,025,525	3,224,919			
1898—Acres.....	21,367,295	3,033,176	1,876,487	152,452	3,535,205	1,281,261	2,900,298	82,498	1,311,708	530,792	1,323,213	896,722	3,363,160	13,980		
Bales.....	11,189,206	1,176,042	919,409	35,064	1,378,731	717,747	1,247,128	33,207	689,620	316,864	1,035,414	322,820				
1897—Acres.....	24,319,534	2,708,460	1,619,785	251,109	3,537,702	1,245,389	2,778,610	83,784	1,302,437	634,656	2,074,773	967,077	7,164,175	50,612		
Bales.....	10,897,837	837,112,681	942,267	53,637	1,350,761	524,771	1,082	646,728	217,082	317,561	1,030,085	912,337	6,758,656	47,747		
1896—Acres.....	23,273,209	2,658,333	1,542,632	264,325	3,468,355	1,246,399	2,835,316	79,373	1,228,714	219,674	2,014,348	912,337	6,758,656	47,747		
Bales.....	8,532,705	833,643	48,750	1,289,340	567,251	1,201,000	24,717	531,798	122,936	936,463	236,731	2,122,701	11,539			
1895—Acres.....	20,184,808	2,371,726	1,186,635	191,540	3,069,323	1,142,668	2,487,119	48,212	1,050,183	238,940	1,844,728	712,763	5,826,428	44,623		
Bales.....	7,161,094	663,916	520,860	38,722	1,067,377	541,843	1,031,358	11,934	327,700	82,771	754,700	1,905,337	7,161,094			
1894—Acres.....	23,687,930	644,561	1,483,319	3,610,968	1,313,298	2,826,272	2,826,272	262,107	2,065,529	262,107	2,065,529	187,747	6,854,621	61,128		
Bales.....	9,001,251	990,439	748,206	50,729	1,247,932	760,757	1,231,227	25,53	479,441	135,566	862,604	304,981	3,140,392	13,414		

TABLE LV.—COTTON ACREAGE HARVESTED, AND PRODUCTION, BY STATES, FOR SELECTED YEARS, 1839 TO 1925 (Continued)

Growth year	United States	Alabama	Arkansas	Florida	Georgia	Louisiana	Mississippi	North Carolina	North Oklahoma	South Carolina	Tennessee	Texas	Virginia
1889—Acres	20,175,270	2,761,165	1,700,578	227,370	3,345,101	1,270,154	2,883,278	60,620	1,447,136	71,187	1,987,469	747,471	3,934,525
1889—Bales	7,472,511	915,210	691,484	57,328	1,101,846	659,190	1,154,725	16,941	336,261	34,540	747,190	190,570	1,471,242
1884—Acres	17,439,612	2,740,941	1,259,488	268,111	4,468,930	922,581	1,392,447	70,920	1,061,048	(c)	1,716,128	815,638	3,186,688
1884—Bales	5,682,000	648,700	531,400	57,300	907,400	485,200	883,200	30,200	404,100	(c)	511,800	995,400	13,500
1879—Acres	14,480,019	2,330,046	1,042,976	245,505	2,617,138	864,737	2,106,215	34,783	888,153	1,364,249	722,562	2,178,435	45,040
1879—Bales	5,755,359	699,654	608,236	54,397	814,441	508,569	963,111	21,685	388,598	532,548	330,621	805,284	19,595
1860—Baled <sup>a</sup>	3,011,996	429,482	247,968	30,789	473,934	350,832	564,938	2,965	144,935	224,500	131,942	350,628	183
1859—Baled <sup>a</sup>	3,387,052	989,955	367,383	65,153	701,840	777,738	1,292,507	42,986	145,514	353,412	298,484	431,463	12,727
1849—Baled <sup>a</sup>	2,469,893	364,459	63,344	4,131	499,971	178,737	484,292	73,945	—	300,901	194,532	3,947	—
1839—Baled <sup>a</sup>	2,043,915	305,846	31,620	1,571	398,317	123,612	501,965	2,602	135,578	161,123	72,327	—	9,124

<sup>a</sup> Includes statistics for other cotton-producing localities not named, also, for Oklahoma and Virginia in 1893 and for Oklahoma in 1894.<sup>b</sup> The data for 1924 relate to acreage planted.<sup>c</sup> Included with Missouri.<sup>d</sup> The statistics of bales for 1849, 1859, and 1869 are in equivalent 400-pound bales, as expressed in the census reports for those years; those for 1859 are in equivalent bales of 383 pounds, net weight.

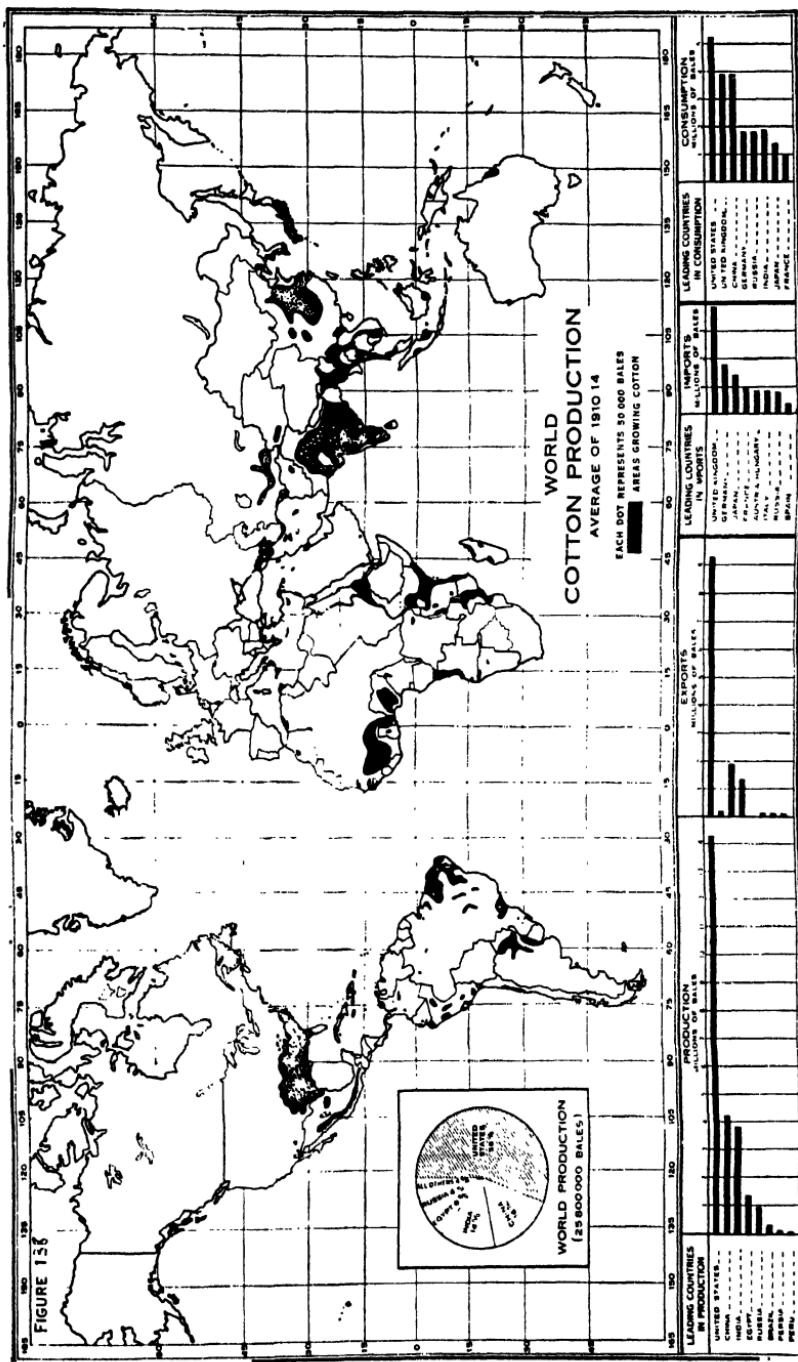


FIG. 138.—Cotton-producing areas of the world. (After U. S. Dept. Agric.)

**World's Production and Consumption of Cotton.**—The sources of information in detail as to the production, consumption,

**COTTON**  
**ACREAGE, YIELD PER ACRE AND PRODUCTION**  
**UNITED STATES, 1866-1921**

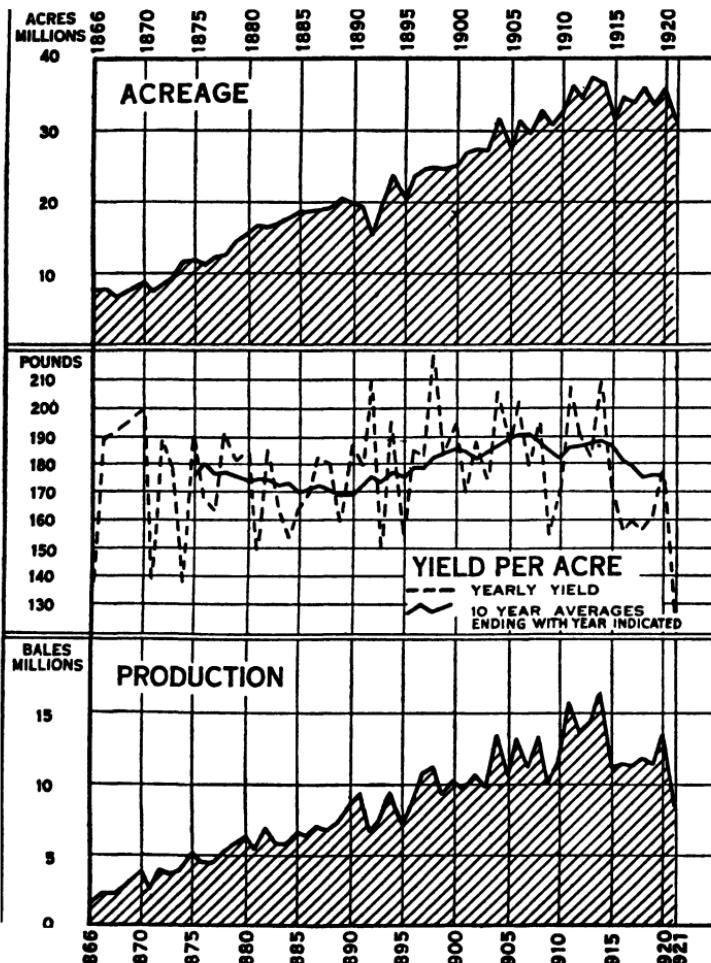


FIG. 139.—The acreage of cotton expanded rapidly from 1866 to 1913. The trend from 1913 to 1921 was downward. The yield per acre varies greatly year to year. The trend was upward from 1890 to 1907 and downward from 1907 to 1921. The crop of 1921 was the smallest since 1895. (After U. S. Dept. Agric.)

and stocks of cotton have never been adequate or altogether satisfactory for many countries. The United States is the only coun-

try which has provided an efficient means of determining the supply and distribution of cotton within its borders. Other governments in the principal cotton-producing countries have been providing estimates, approximately correct and practically reliable. The Indian government publishes a memorandum from time to time during the cotton year based upon estimates received from the several producing provinces and the statistics of yarn production compiled from returns of the spinners. The Egyptian government publishes monthly returns showing the number and weight of steam-pressed bales from Sept. 1 of each season to the date to which the report relates, but complete data are not available until the end of the year, and do not necessarily represent the actual growth of the season.

Information as to production, consumption, and stocks in all countries except the United States is compiled from reports transmitted by the representatives of the government in foreign countries and from special correspondence, trade reports, and such accounts of the movements of cotton as are available.

While the average weight of the American bale approximates 500 pounds, the weights of the packages into which the several foreign cottons are packed vary from 200 pounds or less to 750 pounds or more. For this reason the statistics for all of these countries have been expressed in bales of 478 pounds, which is practically equivalent to a 500-pound gross-weight bale, in order to provide a practical unit for comparative purposes which will at the same time convey the conventional idea of actual quantity.

TABLE LVI.—WORLD'S PRODUCTION OF COMMERCIAL COTTON, BY COUNTRIES, 1919 TO 1924

Country	Cotton production (bales of 478 pounds lint)					
	1924	1923	1922	1921	1920	1919
Total.....	23,285,000	18,969,000	17,959,000	15,334,000	19,665,000	20,220,000
United States.....	13,628,000	10,140,000	9,762,000	7,954,000	13,440,000	11,425,000
India <sup>a</sup> .....	5,100,000	4,400,000	4,220,000	4,200,000	2,600,000	4,475,000
Russia <sup>b</sup> .....	453,000	260,000	55,000	43,000	85,000	440,000
Egypt.....	1,450,000	1,271,000	1,229,000	902,000	1,285,000	1,305,000
China.....	1,320,000	1,420,000	1,360,000	1,030,000	1,045,000	1,150,000
Brazil.....	605,000	575,000	535,000	540,000	450,000	560,000
Mexico.....	280,000	138,000	178,000	147,000	215,000	210,000
Peru.....	200,000	200,000	190,000	175,000	155,000	175,000
All other countries	789,000	562,000	430,000	343,000	390,000	480,000

<sup>a</sup> The amounts for India do not include cotton used in home manufacture, although such cotton is included in the reports of cotton produced compiled by the India government.

<sup>b</sup> Consists of cotton exported and cotton consumed in spinning mills.

Table LVI gives the world's production of commercial cotton—that is, cotton destined to enter commercial channels for factory purposes—from the crops of 1919 to 1924, inclusive, for the more important cotton-growing countries.

TABLE LVII.—PRODUCTION OF UPLAND, SEA ISLAND, AND AMERICAN-EGYPTIAN IN THE UNITED STATES, CROPS OF 1899-1924

Growth year	Cotton (exclusive of linters)					Linters	
	Running bales, counting round as half bales	Equivalent 500-pound bales	Running bales			Running bales	Equivalent 500-pound bales
			Total	Upland			
				Square <sup>a</sup>	Round		
1924	13,639,399	13,627,936	13,796,561	13,482,225	314,325	11	857,962
1923	10,170,694	10,139,671	10,291,847	10,048,755	242,307	785	639,540
1922	9,729,306	9,762,069	9,815,397	9,638,090	172,182	5,125	590,537
1921	7,977,778	7,953,641	8,039,673	7,912,555	123,791	3,327	382,375
1920	13,270,970	13,439,603	13,374,237	13,165,835	206,534	1,868	429,005
1919	11,325,532	11,420,763	11,382,684	11,261,463	114,305	6,916	505,093
1918	11,906,480	12,040,532	11,983,582	11,777,170	154,204	52,208	910,236
1917	11,248,242	11,302,375	11,342,780	11,061,085	189,076	92,619	1,096,422
1916	11,363,915	11,449,930	11,460,084	11,150,183	192,330	117,559	1,300,163
1915	11,068,173	11,191,820	11,124,031	10,920,471	111,716	91,844	944,640
1914	15,905,840	16,134,930	15,934,649	15,795,377	57,618	81,654	832,401
1913	13,982,811	14,156,486	14,032,792	13,855,267	99,962	77,563	631,153
1912	13,488,539	13,703,421	13,529,303	13,373,998	81,528	73,777	602,324
1911	15,553,073	15,692,701	15,603,850	15,383,003	101,554	119,293	556,276
1910	11,568,334	11,608,616	11,624,777	11,421,522	112,887	90,368	307,628
1909	10,072,731	10,004,949	10,148,076	9,902,595	150,690	94,791	313,478
1908	13,086,005	13,241,799	13,207,157	12,870,994	242,305	93,858	346,126
1907	11,057,822	11,107,179	11,157,096	10,871,652	198,549	86,895	268,060
1906	12,983,201	13,273,808	13,117,310	12,791,541	268,219	57,550	322,064
1905	10,495,105	10,575,017	10,635,023	10,242,648	279,836	112,539	230,497
1904	13,451,337	13,438,012	13,509,412	13,198,944	206,151	104,317	245,973
1903	9,819,069	9,851,129	10,205,073	9,350,472	770,208	75,393	195,752
1902	10,588,250	10,630,945	11,078,882	9,992,665	981,264	104,953	196,223
1901	9,582,520	9,509,745	9,954,045	9,132,215	744,851	77,879	166,026
1900	10,102,102	10,123,027	10,486,148	9,629,762	768,092	88,294	143,500
1899	9,393,242	9,345,391	9,645,974	9,043,231	505,464	97,279	114,544

<sup>a</sup> Includes 22,426 American-Egyptian bales for 1923; 32,824 bales for 1922; 37,094 bales for 1921; 92,561 bales for 1920; 40,437 bales for 1919; and 36,187 bales for 1918.

TABLE LVIII.—STOCKS OF "AMERICAN" AND "ALL KINDS" OF COTTON AT SPECIFIED LOCATIONS ON JULY 31, 1924

(These figures do not include cotton at locations other than specified. They have been taken from a number of sources, among which are publications of the International Federation of Master Cotton Spinners' and Manufacturers' Associations, Liverpool Cotton Association, and the Alexandria Commercial Company. American cotton is given in running bales and other cottons in equivalent bales of 478 pounds lint. Linters in the United States are not included.)

Location	American, bales	All kinds, bales
Mill stocks:		
United States.....	638,000	722,000
United Kingdom.....	83,000	222,000
Other European countries.....	417,000	844,000
All other countries.....	187,000	1,475,000
Stocks in public storage in the United States.....	641,000	674,000
Port stocks:		
United Kingdom.....	200,000	440,000
Other European countries.....	194,000	282,000
Alexandria.....	.....	77,000
Brazil (Rio de Janeiro, Pernambuco, São Paulo).....	.....	23,000
Cotton afloat:		
To United Kingdom.....	28,000	109,000
To other European countries.....	116,000	184,000
Stocks held elsewhere in the United States <sup>a</sup> .....	160,000	160,000

<sup>a</sup> Includes cotton for export on shipboard but not cleared; cotton coastwise; cotton in transit to ports, interior towns and mills; cotton on farms and in private storage.

TABLE LIX.—EXPORTS OF DOMESTIC COTTON AND LINTERS—VALUE AND QUANTITY, WITH DISTRIBUTION OF QUANTITY, BY COUNTRIES TO WHICH EXPORTED, 1892 TO 1925  
(Compiled from *Commerce and Navigation of the United States*. The figures in this table are for fiscal years.)

Year	Total value	Exports of domestic cotton (equivalent 500-pound bales) to—												All other countries		
		Total	United Kingdom	Germany	France	Italy	Spain	Belgium	Russia <sup>a</sup>	Austria <sup>a</sup>	Netherlands	Japan	Canada	Mexico		
1925	\$1,060,980,197	8,439,071	2,623,425	1,891,992	951,473	756,156	289,586	226,741	286,367	571	151,285	849,584	206,853	81	50,527	
1924	903,975,146	5,898,713	1,604,985	1,345,554	751,424	563,733	216,253	188,968	120,318	2,144	112,456	153,233	583,957	151,731	1,082	32,965
1923	658,982,835	5,233,464	1,403,008	945,047	704,199	572,068	250,244	185,769	7,274	2,958	75,018	167,646	679,158	217,052	15,492	27,331
1922	596,378,864	6,717,757	1,806,743	1,616,874	820,049	468,580	341,551	186,272	...	4,008	96,203	135,614	885,367	201,166	6,195	139,325
1921	600,185,629	5,622,777	1,788,864	1,152,424	590,630	558,015	280,990	186,018	...	5,862	98,754	155,086	554,892	169,166	70,602	53,384
1920	1,381,707,502	7,087,487	3,444,754	420,758	596,381	617,263	275,034	209,572	...	42,856	186,476	183,729	876,250	216,906	1,141	16,615
1919	873,579,669	5,525,893	2,494,009	...	773,744	557,549	281,343	72,652	310	55,386	57,949	203,949	809,313	203,015	1,707	14,967
1918	655,024,655	4,641,023	2,387,101	...	638,553	369,213	259,194	...	15,945	...	10,098	82,572	553,546	249,973	10,706	14,122
1917	543,074,690	6,176,162	2,895,423	...	1,058,749	687,158	384,093	...	49,189	...	62,161	184,717	530,892	187,201	5,298	124,281
1916	374,186,247	6,168,140	2,760,880	...	890,376	836,915	340,246	...	173,449	...	102,087	169,154	503,077	197,659	23,695	170,582
1915	376,217,972	8,807,157	3,919,749	294,194	692,689	1,127,400	464,504	5,057	82,125	455	544,035	898,096	428,806	182,790	39,727	127,520
1914	610,475,301	9,521,581	3,581,501	2,884,324	1,139,389	537,357	297,338	227,474	99,076	106,511	35,053	63,725	353,440	150,993	34,671	11,018
1913	547,357,195	9,124,591	3,716,588	2,443,886	1,074,987	500,823	317,951	226,967	74,907	113,182	14,537	55,376	386,779	152,015	20,977	15,303
1912	565,849,271	11,070,251	4,343,108	3,156,171	1,228,294	639,077	313,500	211,903	112,262	125,564	35,242	83,821	480,934	181,667	16,129	145,579
1911	585,318,866	8,067,882	3,461,034	2,202,707	1,021,988	436,296	242,073	150,525	84,041	79,530	18,124	48,713	156,724	156,824	4,631	4,042
1910	450,447,243	6,413,416	2,444,538	1,887,657	968,422	393,327	178,455	102,346	67,203	57,220	18,823	43,378	95,000	125,592	29,604	1,831
1909	417,380,655	8,865,970	3,665,355	2,438,030	1,098,173	565,685	301,780	137,631	96,675	94,782	30,120	58,174	208,943	131,453	42,575	6,506
1908	437,788,202	7,633,997	2,956,332	2,385,063	889,083	418,921	262,744	119,470	98,371	90,049	27,684	62,125	200,396	113,997	4,767	4,375
1907	481,277,797	9,036,434	3,966,119	2,315,651	1,008,633	567,916	275,868	154,168	121,141	113,630	29,092	65,083	262,283	160,343	732	7,775
1906	401,005,921	7,285,090	3,181,143	1,857,441	817,583	458,607	241,747	114,673	112,480	56,375	18,490	44,486	147,269	141,908	29,285	4,603
1905	379,965,014	5,609,098	3,967,254	2,011,679	515,304	534,735	295,537	145,564	129,060	62,572	31,163	72,911	336,575	115,857	79,052	9,405

1904	370,811,246	6,126,386	2,475,759	1,797,354	734,286	363,295	184,862	105,213	168,506	28,156	16,055	61,488	58,795	56,172	580	
1905	316,160,429	7,086,096	2,709,096	1,915,094	806,673	444,950	266,336	157,351	181,938	39,912	42,542	82,243	152,826	127,040	66,507	2,978
1906	290,651,819	7,001,324	1,705,815	775,773	445,437	270,602	132,732	73,446	39,735	22,418	61,679	178,505	129,555	102,980	35,103	7,054
1907	313,673,443	6,681,781	3,106,857	1,629,935	754,329	365,559	237,346	154,682	53,171	37,238	53,180	52,325	75,555	102,980	35,103	718
1908	241,832,737	6,201,166	12,302,128	1,619,173	736,092	443,951	246,612	148,319	54,950	44,919	74,635	65,635	323,202	109,983	15,522	13,045
1899	209,564,774	7,546,921	3,609,444	1,728,975	803,406	417,353	248,635	129,524	35,012	57,127	51,921	64,500	192,734	98,230	36,130	4,130
1899	230,442,215	7,700,529	3,532,101	1,858,525	842,038	347,581	283,648	161,941	103,825	35,614	43,809	69,189	224,214	122,495	42,433	13,416
1897	230,590,971	6,207,510	3,137,186	1,371,577	716,025	323,117	219,088	83,485	84,570	23,971	34,731	48,790	64,022	80,405	30,207	333
1896	190,056,460	4,670,453	2,267,222	1,038,487	478,265	261,644	216,178	87,966	91,622	15,912	14,219	51,367	40,388	63,074	38,817	322
1895	204,900,990	7,034,866	3,553,782	1,504,631	790,699	322,656	255,679	145,340	141,998	24,852	25,998	55,319	22,130	105,534	75,953	294
1894	210,866,289	5,386,565	12,970,903	909,389	610,854	211,716	225,304	128,907	140,082	960	18,581	39,086	9,603	65,085	35,165	270
1893	188,771,445	4,424,230	5,383,176	850,387	568,059	160,019	200,212	90,398	26,356	26,114	22,449	1,586	62,988	41,812	173	
1892	238,461,241	5,870,440	3,381,685	964,883	602,785	171,003	157,455	134,373	134,302	10,052	27,192	35,986	3,149	79,228	44,235	276

<sup>a</sup> Includes Finland and Poland prior to 1919.

<sup>b</sup> Includes Czechoslovakia and Hungary prior to 1920.

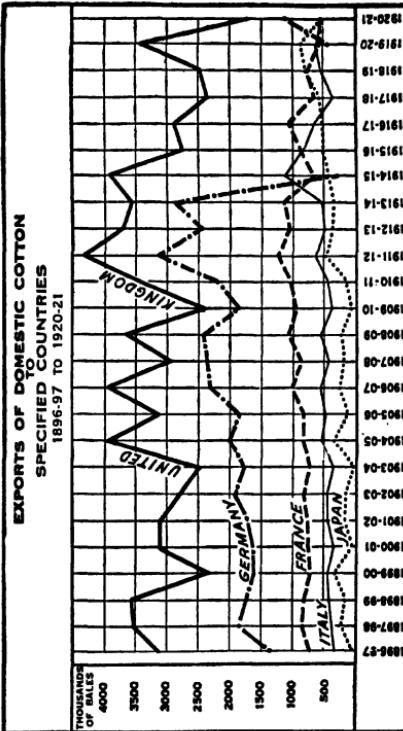


FIG. 140.—Comparative amounts of American cotton exported to the leading consuming countries from 1896 to 1921. (After U. S. Dep. Agric.)

TABLE LX.—NET RECEIPTS OF RAW COTTON AT PRINCIPAL COTTON PORTS, FOR SPECIFIED YEARS, 1875-1924

(Compiled from reports of New Orleans Cotton Exchange. The statistics for 1915 to 1924 relate to the 12 months ending July 31, and those for prior years to the 12 months ending Aug. 31.)

Port	Net receipts of cotton (running bales)							
	1924	1923	1922	1921	1920	1919	1918	1915
Galveston.....	2,875,783	2,345,674	2,551,935	3,144,361	2,101,110	1,933,002	1,621,886	4,001,710
Port Arthur and Texas City.....	16,852	69,917	34,273	46,900	329,637	124,276	80,728	560,103
New Orleans.....	1,372,664	1,365,382	1,277,802	1,504,751	1,366,735	1,635,444	1,664,267	1,810,184
Mobile.....	86,344	90,377	166,317	111,690	265,176	155,516	107,290	166,997
Pensacola.....	6,014	6,049	2,108	...	13,298	4,038	15,024	87,236
Jacksonville and Fernandina.....	6,986	9,584	5,407	5,805	15,617	36,082	38,585	34,770
Brunswick.....	460	25,391	30,224	12,424	168,366	186,114	158,701	215,504
Savannah.....	456,474	454,027	761,971	727,506	1,306,361	1,150,618	1,140,591	1,762,418
Charleston.....	146,605	138,964	156,862	91,269	415,123	217,226	203,879	405,504
Wilmington.....	134,244	107,117	108,019	104,306	142,758	151,882	98,913	270,007
Norfolk and Newport News.....	426,448	287,659	352,764	296,037	351,137	304,012	299,882	829,683
Baltimore.....	31,504	21,547	61,443	51,982	92,263	23,157	80,014	83,114
Philadelphia.....	1,361	4,942	29,800	16,707	21,284	8,065	24,752	11,134
New York.....	25,053	9,541	28,207	37,027	30,229	12,970	149,970	30,022
Boston.....	44,907	77,464	50,046	40,111	44,362	30,175	112,367	88,043
San Francisco.....	84,406	68,842	71,132	81,367	112,390	127,233	158,800	189,561
Seattle and Tacoma.....	53,676	18,465	82,226	191,384	354,965	608,935	416,978	277,269
Houston.....	1,071,798	723,622	480,294	466,185	(a)	(a)	(a)	(a)
Laredo, Eagle Pass, etc.....	2,082	8,150	796	44,271	71,655	...	2,677	9,707
Minor points.....	107,248	102,931	151,359	114,409	67,192	27,063	30,645	52,996

Port	1910	1905	1900	1895	1890	1885	1880	1875
Galveston.....	2,501,412	2,879,336	1,710,263	1,659,909	860,112	463,463	480,352	354,927
Port Arthur and Texas City.....	163,778	(a)	(a)	(a)	(a)	(a)	(a)	(a)
New Orleans.....	1,315,328	2,689,520	1,867,153	2,584,115	1,973,571	1,529,592	1,504,654	903,481
Mobile.....	255,665	329,556	340,646 <sup>b</sup>	253,287	261,957	237,071	358,971	320,822
Pensacola.....	138,234	195,151	(a)	(a)	(a)	(a)	(a)	(a)
Brunswick.....	227,301	199,193	94,278	(a)	(a)	(a)	(a)	(a)
Savannah.....	1,365,825	1,877,343	1,088,807	944,410	956,517	728,087	741,018	606,727
Charleston.....	228,728	225,366	265,523	425,487	327,079	507,802	464,332	412,931
Wilmington.....	312,511	375,383	282,360	234,621	134,916	94,054	78,876	76,601
Norfolk and Newport News.....	587,363	841,174	432,727	472,540	404,056	545,418	590,032	387,279
Baltimore.....	85,526	72,427	101,648	(a)	(a)	(a)	(a)	(a)
Philadelphia.....	2,581	13,645	36,238	(a)	(a)	(a)	(a)	(a)
New York.....	40,706	33,798	119,215	187,794	176,502	99,200	229,426	179,163
Boston.....	14,792	83,644	118,891	(a)	(a)	(a)	(a)	(a)

<sup>a</sup> Not shown separately.<sup>b</sup> Includes receipts of Pensacola.<sup>c</sup> Included in receipts of Mobile.

TABLE LXI.—NUMBER OF ACTIVE AND IDLE GINNERSIES, AND AVERAGE NUMBER OF RUNNING BALES, EXCLUDING LINTERS, GINNED PER ACTIVE ESTABLISHMENT, BY STATES, 1920-1923

State	Growth year	Number of ginneries			Average number of running bales ginned per active establishment	State	Growth year	Number of ginneries			Average number of running bales ginned per active establishment
		Total	Active	Idle				Total	Active	Idle	
United States...	1923	19,195	15,298	3,897	665	Missouri.....	1923	144	136	8	917
	1922	19,939	15,420	4,519	631		1922	101	94	7	1,488
	1921	20,938	16,192	4,746	493		1921	103	78	25	874
	1920	21,876	18,440	3,436	720		1920	110	94	16	812
Alabama.....	1923	1,750	1,364	386	439	North Carolina...	1923	2,070	1,690	380	623
	1922	1,840	1,427	413	575		1922	2,140	1,730	410	508
	1921	1,922	1,415	507	415		1921	2,237	1,807	430	445
	1920	2,040	1,585	455	423		1920	2,358	1,961	397	484
Arizona.....	1923	63	46	17	1,689	Oklahoma.....	1923	931	853	78	781
	1922	54	36	18	1,226		1922	933	770	163	827
	1921	51	36	15	1,192		1921	961	737	224	648
	1920	52	50	2	2,104		1920	1,018	963	55	1,353
Arkansas.....	1923	1,540	1,353	187	476	South Carolina	1923	2,048	1,779	869	446
	1922	1,582	1,400	182	722		1922	2,850	1,788	1,062	289
	1921	1,653	1,462	191	539		1921	3,029	2,258	771	348
	1920	1,702	1,531	171	772		1920	3,127	2,757	370	599
California.....	1923	41	26	15	2,127	Tennessee.....	1923	518	449	69	524
	1922	46	26	20	1,095		1922	509	448	61	861
	1921	49	30	19	1,160		1921	539	454	85	655
	1920	51	45	6	1,731		1920	572	480	92	656
Florida.....	1923	135	68	67	200	Texas.....	1923	3,791	3,511	280	1,200
	1922	149	84	65	327		1922	3,772	3,340	432	936
	1921	165	73	92	167		1921	3,905	3,176	729	671
	1920	198	87	111	223		1920	4,047	3,592	455	1,155
Georgia.....	1923	2,677	1,715	962	357	Virginia.....	1923	142	124	18	419
	1922	2,914	1,800	1,024	389		1922	136	110	26	246
	1921	3,152	2,218	934	371		1921	134	106	28	157
	1920	3,313	2,639	674	548		1920	136	115	21	190
Louisiana.....	1923	962	720	242	519	All other states*	1923	32	31	1	1,118
	1922	1,042	748	294	462		1922	18	16	2	1,222
	1921	1,095	703	302	350		1921	16	14	2	624
	1920	1,149	884	265	441		1920	15	14	1	950
Mississippi.....	1923	1,751	1,433	318	434						
	1922	1,853	1,513	340	652						
	1921	1,927	1,535	392	532						
	1920	1,988	1,643	345	548						

\* Includes Illinois, Kansas, Kentucky, and New Mexico.

TABLE LXII.—PER CENT OF THE TOTAL COTTON GINNED TO SPECIFIED DATES, BY STATES, 1920-1923

State	Growth year	Per cent of total cotton ginned to—								
		Sept. 1	Sept. 25	Oct. 18	Nov. 1	Nov. 14	Dec. 1	Dec. 13	Jan. 1	Jan. 16
United States....	1923	11.2	31.8	36.0	74.3	82.3	90.9	93.9	96.4	97.8
	1922	8.3	39.7	71.7	83.7	91.2	95.8	97.5	98.6	99.2
	1921	6.1	36.6	68.9	83.3	91.2	95.8	97.7	98.8	99.2
	1920	2.6	17.0	43.4	56.6	67.2	76.4	82.0	87.1	90.5
Alabama.....	1923	0.8	26.9	66.6	82.1	91.6	97.4	98.7	99.3	99.5
	1922	6.8	40.2	74.4	86.8	94.3	98.1	99.1	99.6	99.7
	1921	2.2	39.2	72.7	87.2	94.3	97.7	98.8	99.4	99.5
	1920	0.2	12.5	42.1	61.5	75.0	85.0	90.2	94.3	96.2
Arizona.....	1923	1.0	9.8	28.9	43.5	52.4	67.2	74.3	80.3	88.4
	1922	(*)	4.6	23.2	37.4	50.3	64.5	71.3	83.1	90.9
	1921	0.3	6.9	20.2	31.9	43.7	60.1	70.6	82.6	89.6
	1920	0.3	5.3	18.7	28.6	38.4	54.2	63.5	73.7	83.3
Arkansas.....	1923	0.7	7.6	47.3	60.9	73.1	87.4	91.0	94.5	96.4
	1922	0.5	27.8	64.5	81.8	91.6	96.6	97.9	98.8	99.4
	1921	(*)	20.0	59.4	79.4	90.6	95.9	98.1	99.2	99.6
	1920	(*)	4.8	29.7	44.2	57.0	69.1	75.3	81.2	86.0
California.....	1923	1.8	7.8	21.9	37.5	46.5	59.2	64.6	72.2	82.0
	1922	0.2	3.7	16.6	29.9	45.1	60.9	74.1	83.3	86.9
	1921	0.5	4.3	11.3	19.7	30.6	45.2	56.8	66.7	75.5
	1920	2.3	8.7	17.9	24.8	32.6	42.0	49.0	60.5	72.3
Florida.....	1923	5.9	33.9	75.8	83.8	93.2	96.0	98.1	98.6	98.9
	1922	19.6	46.2	74.0	82.0	93.0	95.6	98.9	99.6	99.7
	1921	3.2	35.1	67.1	76.9	91.8	96.2	98.6	99.1	99.4
	1920	0.6	16.9	50.4	60.6	77.0	82.4	91.5	93.7	95.4
Georgia.....	1923	3.2	30.4	67.5	79.8	88.6	95.0	97.9	98.9	99.2
	1922	19.2	50.7	77.3	85.9	92.6	96.8	98.4	99.2	99.4
	1921	5.8	47.7	77.4	89.5	94.9	97.6	98.7	99.3	99.5
	1920	1.0	19.3	50.2	68.8	80.5	86.8	91.2	94.3	95.7
Louisiana.....	1923	3.3	29.0	66.4	79.3	88.0	95.3	97.1	98.1	98.6
	1922	4.2	46.1	79.9	90.3	95.2	98.2	99.0	99.6	99.7
	1921	1.0	35.7	68.6	83.3	91.7	97.0	98.2	99.1	99.3
	1920	0.7	22.3	52.5	69.5	76.8	85.8	91.0	95.0	96.7
Mississippi.....	1923	0.2	17.6	56.3	73.5	85.6	95.5	97.8	98.5	98.9
	1922	1.1	35.8	70.6	85.2	93.4	97.7	99.0	99.5	99.6
	1921	0.5	30.7	62.5	78.6	89.7	96.6	98.5	99.4	99.5
	1920	0.1	10.7	38.8	55.3	67.8	80.3	86.2	91.2	93.4
Missouri.....	1923	...	0.6	29.3	43.1	53.4	70.7	75.5	82.7	88.8
	1922	(*)	14.9	45.1	64.6	80.1	90.9	93.5	96.2	98.4
	1921	(*)	20.9	59.4	81.2	94.0	97.1	98.9	99.7	99.7
	1920	...	0.3	17.8	35.1	46.6	57.8	64.7	72.2	80.3

than one-tenth of 1 per cent.

TABLE LXII.—PER CENT OF THE TOTAL COTTON GINNED TO  
SPECIFIED DATES, BY STATES, 1920-1923 (Continued)

State	Growth year	Per cent of total cotton ginned to—								
		Sept. 1	Sept. 25	Oct. 18	Nov. 1	Nov. 14	Dec. 1	Dec. 13	Jan. 1	Jan. 16
North Carolina.....	1923	(a)	14.9	53.5	69.3	79.0	89.3	93.7	96.5	97.6
	1922	0.1	17.0	50.5	65.6	78.7	90.0	94.4	96.7	98.0
	1921	(a)	17.6	55.2	72.4	83.6	91.9	95.5	97.5	98.4
	1920	(a)	3.3	20.1	37.5	52.8	64.4	71.7	79.4	84.5
Oklahoma.....	1923	0.9	9.6	32.9	44.4	55.3	76.3	84.9	93.2	96.6
	1922	0.5	29.1	69.0	84.8	92.6	97.0	98.3	99.3	99.5
	1921	0.3	29.4	73.8	91.1	96.7	98.5	99.2	99.7	99.8
	1920	(a)	5.1	29.0	36.5	47.1	59.2	66.1	74.2	80.9
South Carolina.....	1923	0.3	24.2	64.0	79.0	87.7	94.5	97.1	98.4	98.8
	1922	0.9	28.6	65.0	79.8	89.4	95.3	97.1	98.2	98.8
	1921	0.1	27.4	62.7	79.2	87.1	93.5	96.4	98.0	98.7
	1920	(a)	10.4	34.0	52.5	66.5	76.2	82.6	88.0	91.2
Tennessee.....	1923	...	1.4	35.1	52.0	66.8	85.0	89.9	93.9	95.7
	1922	(a)	13.9	52.8	72.8	85.9	94.7	96.7	98.1	99.0
	1921	(a)	14.2	53.8	75.0	87.5	94.4	98.1	99.2	99.5
	1920	...	0.3	17.0	36.6	52.6	66.6	74.8	83.0	88.1
Texas.....	1923	25.9	51.8	76.4	83.1	87.8	93.0	94.9	97.0	98.3
	1922	18.1	57.4	84.5	91.1	94.7	96.6	97.9	98.9	99.3
	1921	19.5	57.4	81.6	90.6	95.2	97.5	98.5	99.4	99.6
	1920	7.9	32.8	62.6	69.9	76.1	82.5	86.7	90.3	93.1
Virginia.....	1923	....	1.7	27.4	42.3	57.8	72.8	83.1	89.3	92.3
	1922	....	2.5	29.4	50.4	72.3	86.3	92.5	95.2	96.2
	1921	....	6.8	45.1	63.8	79.8	90.2	94.5	96.5	98.0
	1920	....	...	5.0	14.1	29.4	45.1	56.5	62.8	66.6
All other states....	1923	....	3.0	22.8	37.4	48.0	65.3	71.3	75.3	83.6
	1922	....	6.6	24.5	37.3	52.3	74.6	82.0	90.3	95.1
	1921	....	4.3	41.4	58.7	74.2	84.7	94.7	97.5	99.6
	1920	....	...	15.3	23.4	34.2	49.8	62.9	72.9	85.6

\* Less than one-tenth of 1 per cent.

\* Includes Illinois, Kansas, Kentucky, and New Mexico

TABLE LXIII.—PERCENTAGE REDUCTION FROM FULL YIELD PER ACRE OF COTTON FROM STATED CAUSES, AS REPORTED BY CROP CORRESPONDENTS, 1909-1924

Year	Defi- cient mois- ture	Exces- sive mois- ture	Other cli- matic	Total cli- matic	Plant dis- eases	Insect pests	Other or un- known	Total
1924	14.0	5.0	2.3	21.3	0.8	12.0	0.6	34.7
1923	7.2	8.0	2.8	18.0	0.7	26.6	0.2	45.5
1922	10.3	4.9	2.3	17.5	0.8	26.7	0.2	45.2
1921	8.6	4.3	3.1	16.0	1.0	35.4	0.5	52.9
1920	2.2	8.8	2.1	13.1	1.1	24.0	0.8	39.0
1919	2.7	15.3	3.2	21.2	1.4	18.8	0.5	41.9
1918	23.8	0.9	4.5	29.2	2.0	7.9	1.2	40.3
1917	15.1	1.7	8.7	25.5	1.3	12.3	0.8	39.9
1916	9.2	9.1	6.9	25.2	0.9	15.7	0.6	42.4
1915	6.8	5.7	6.8	19.3	1.9	12.2	3.4	36.8
1914	7.9	2.9	3.0	13.8	0.2	9.8	1.6	25.4
1913	15.2	2.0	5.9	23.1	0.5	8.9	1.2	33.7
1912	8.1	7.6	5.0	20.7	4.3	6.5	1.2	32.7
1911	9.8	2.6	3.0	15.4	0.4	7.9	2.4	26.1
1910	12.2	5.1	5.3	22.6	0.4	7.5	5.1	35.6
1909	14.9	6.0	7.7	28.6	4.2	7.9	1.3	42.0

TABLE LXIV.—WORLD'S CONSUMPTION OF COTTON, SEASONS OF 1919-1920 TO 1923-1924

Country	Mill consumption of cotton (bales of 478 pounds lint, except American, which are in running bales)				
	1923-24	1922-23	1921-22	1920-21	1919-20
Total.....	19,982,000	21,325,000	19,990,000	16,905,000	19,300,000
United States (exclusive of linters).....	5,681,000	6,666,000	5,910,000	4,905,000	6,485,000
Europe:					
United Kingdom.....	2,842,000	2,825,000	2,900,000	2,135,000	3,870,000
Continent.....	5,551,000	5,304,000	5,016,000	4,600,000	3,830,000
India.....	1,630,000	1,751,000	1,871,000	1,925,000	1,720,000
Japan.....	2,037,000	2,348,000	2,176,000	1,885,000	1,910,000
Canada.....	152,000	203,000	205,000	155,000	230,000
All other countries.....	2,089,000	2,228,000	1,912,000	1,300,000	1,255,000

TABLE LXV.—WORLD'S COTTON SPINDLES (ACTIVE AND IDLE), 1924

Country	Number of cotton spindles	Country	Number of cotton spindles
Total.....	159,109,000	Europe—Continued:	
United States.....	37,804,000	Netherlands.....	686,000
Europe:		Sweden.....	568,000
United Kingdom.....	56,750,000	Estonia.....	576,000
France.....	9,359,000	Portugal.....	503,000
Germany.....	9,464,000	Finland.....	251,000
Russia.....	7,246,000	Other Europe.....	604,000
Italy.....	4,570,000	India.....	7,928,000
Czechoslovakia.....	3,460,000	Japan.....	4,825,000
Spain.....	1,813,000	China.....	3,300,000
Belgium.....	1,741,000	Brazil.....	1,700,000
Switzerland.....	1,515,000	Canada.....	1,167,000
Poland.....	1,101,000	Mexico.....	802,000
Austria.....	1,051,000	All other countries.....	325,000

TABLE LXVI.—NUMBER OF ACTIVE RING AND MULE COTTON SPINDLES,  
BY STATES, FOR SPECIFIED YEARS, 1924, 1909, AND 1899

State	Number of active cotton spindles					
	1924		1909		1899	
	Ring	Mule	Ring	Mule	Ring	Mule
United States.....	33,529,602	2,319,736	23,256,023	4,922,839	13,444,872	5,563,480
Alabama.....	1,356,638	.....	909,587	3,916	403,328	8,000
Connecticut.....	883,292	344,378	832,830	446,586	607,448	393,126
Georgia.....	2,718,860	38,620	1,703,071	71,896	730,619	84,926
Illinois.....	58,782	.....	23,240	16,000	15,488	16,000
Indiana.....	81,480	.....	115,152	8,952	86,168	16,320
Kentucky.....	80,356	10,928	68,124	16,920	48,234	18,399
Louisiana.....	94,748	.....	63,096	4,806	55,600	.....
Maine.....	1,105,972	27,760	867,364	161,316	584,573	256,948
Maryland.....	104,500	.....	133,302	.....	154,064	.....
Massachusetts.....	9,412,810	1,176,418	7,480,902	2,156,699	5,228,371	2,556,316
Mississippi.....	177,508	.....	159,104	800	75,122	.....
Missouri.....	31,336	312	30,304	440	13,654	.....
New Hampshire.....	1,218,408	19,670	1,169,850	156,050	956,390	287,165
New Jersey.....	270,546	167,308	107,381	313,403	64,638	367,092
New York.....	897,400	54,240	547,512	415,329	333,132	367,136
North Carolina.....	5,750,726	12,608	2,886,453	71,782	1,098,080	35,352
Pennsylvania.....	143,036	26,180	139,062	139,245	182,190	124,447
Rhode Island.....	2,320,136	412,384	1,496,434	875,343	940,204	940,328
South Carolina.....	5,211,508	4,320	3,732,063	28,828	1,420,597	10,752
Tennessee.....	449,160	10,000	237,530	10,000	103,116	20,780
Texas.....	193,100	.....	97,628	.....	48,756	.....
Vermont.....	134,608	10,200	75,872	15,840	56,712	43,316
Virginia.....	684,460	4,410	316,970	7,572	124,502	2,325
All other states.....	150,232	.....	63,192	1,116	93,796	14,752

TABLE LXVII.—TOTAL IMPORTS OF COTTON, AND COUNTRIES OF PRODUCTION, FOR YEARS ENDING JULY 31, 1914, TO 1924, AND FOR EACH MONTH FROM AUGUST, 1920, TO JULY, 1924, INCLUSIVE

Month	Year	Imports of foreign cotton (equivalent 500-pound bales)						
		Total	Produced in—					
			Egypt	China	Peru	India	Mexico	All other countries
Total.....	1925	313,328	190,313	33,703	13,389	28,147	44,384	3,392
	1924	292,288	164,152	45,118	19,928	34,419	27,062	1,609
	1923	469,954	329,335	50,239	21,186	22,124	45,079	1,391
	1922	363,465	233,729	15,563	38,753	10,348	53,637	11,435
	1921	226,341	87,168	14,722	22,597	8,489	88,155	5,210
	1920	700,214	485,004	57,185	63,426	14,358	65,343	14,898
	1919	201,585	100,006	10,871	25,230	2,893	54,434	8,151
	1918	221,216	114,580	38,964	19,092	7,096	35,726	5,158
	1917	291,957	199,892	36,063	11,069	3,860	32,858	8,215
	1916	437,574	350,796	35,792	10,909	4,214	30,098	5,765
	1915	382,286	252,373	25,631	10,353	7,845	65,180	904
	1914	260,988	138,579	20,772	12,267	7,849	80,285	876
August.....	1923	3,420	1,075	386	479	1,439	40	1
	1922	14,678	11,217	480	710	1,942	.....	329
	1921	5,631	4,728	306	73	494	.....	30
	1920	23,106	12,876	2,744	4,057	1,760	.....	1,669
September.....	1923	6,608	4,257	108	1,296	856	89	2
	1922	5,012	2,261	264	776	1,408	58	245
	1921	6,361	3,396	.....	928	935	300	802
	1920	18,816	2,492	3,269	6,949	3,833	798	1,475
October.....	1923	7,615	3,654	124	3,339	316	139	43
	1922	26,816	16,776	.....	1,461	225	8,354	
	1921	31,269	18,972	41	5,302	962	5,531	461
	1920	13,825	12	3,762	1,303	1,581	7,029	138
November.....	1923	16,564	11,488	124	4,339	283	238	92
	1922	49,551	30,399	1,156	3,966	12	13,929	89
	1921	51,440	27,126	.....	7,855	333	15,257	869
	1920	22,513	2,941	.....	1,004	515	18,037	16
December.....	1923	35,173	28,391	330	5,640	790	17	5
	1922	68,547	52,191	2,310	2,737	56	11,047	206
	1921	61,006	41,224	.....	5,550	605	11,847	1,780
	1920	25,890	8,083	481	510	.....	16,798	18
January.....	1924	47,693	40,443	4,556	1,238	597	859	
	1923	105,215	89,626	7,025	1,677	336	6,439	12
	1922	42,093	25,930	1,383	3,779	66	10,034	901
	1921	24,024	7,055	478	638	.....	15,564	289
February.....	1924	48,602	12,749	8,010	1,731	8,144	17,762	206
	1923	66,329	48,325	10,739	2,778	686	3,793	8
	1922	55,024	36,242	4,564	6,392	70	7,246	510
	1921	28,055	7,908	1,417	2,064	6	16,619	41

TABLE LXVII.—TOTAL IMPORTS OF COTTON, AND COUNTRIES OF PRODUCTION, FOR YEARS ENDING JULY 31, 1914, TO 1924, AND FOR EACH MONTH FROM AUGUST, 1920, TO JULY, 1924,  
INCLUSIVE (Continued)

Month	Year	Imports of foreign cotton (equivalent 500-pound bales)						
		Total	Produced in—					All other countries
			Egypt	China	Peru	India	Mexico	
March	1924	49,833	20,617	9,058	281	4,535	5,723	619
	1923	53,219	37,006	6,970	3,655	4,191	1,211	186
	1922	59,957	47,636	4,532	2,246	784	3,122	1,637
	1921	27,282	13,588	1,292	1,873	.....	10,127	402
April	1924	40,435	16,026	13,266	495	8,545	1,513	590
	1923	37,271	16,991	14,102	1,681	4,068	284	145
	1922	15,115	8,817	866	1,499	2,906	286	741
	1921	18,731	15,190	242	616	1	2,533	149
May	1924	16,107	6,760	4,384	128	4,337	492	6
	1923	23,593	14,034	3,012	723	5,525	202	97
	1922	14,320	7,357	1,768	1,109	877	14	3,195
	1921	10,542	6,369	99	2,474	20	625	955
June	1924	13,641	7,566	2,506	470	3,086	.....	13
	1923	13,367	6,580	3,479	430	2,568	249	61
	1922	12,662	7,005	1,507	1,617	2,314	.....	219
	1921	10,105	8,202	657	473	695	25	53
July	1924	6,597	2,126	2,266	492	1,491	190	32
	1923	6,356	3,929	702	592	1,107	13	13
	1922	8,587	5,296	596	2,403	2	.....	290
	1921	3,452	2,452	281	636	78	.....	5

TABLE LXVIII.—ESTIMATED QUANTITY OF COTTON SEED PRODUCED, QUANTITY OF COTTON SEED CRUSHED, ESTIMATED QUANTITIES AND VALUES OF CRUDE PRODUCTS OBTAINED, AND EXPORTS OF COTTON SEED PRODUCTS, 1875-1924  
 (In the preparation of this table a number of sources of information have been utilized, but it has been found impracticable to secure in all instances satisfactory data for the years indicated, and only an approximation to the facts is claimed. Statistics of the quantity of seed produced relate to the preceding crop year and the quantity crushed and of cotton seed products to the year ending July 31, while the statistics of exports are for the year ending June 30.)

Year	Cotton seed		Crude cotton seed products				Exports					
	Produced, tons <sup>a</sup>	Crushed, tons	Oil		Cotton and meal		Hulls		Quantity, bales of 500 pounds net	Value	Oil, gallons	Cotton meal, tons
			Quantity, gallons	Value	Quantity, tons	Value	Quantity, tons	Value				
1874.....	4,502,000	3,307,598	\$182,137,000	\$30,615,609	\$88,068,000	1,517,889	\$59,300,000	941,030	\$12,737,000	642,348	\$22,007,000	5,285,672
Alabama.....	260,000	128,101	7,775,000	5,480,640	3,782,000	58,339	3,229,000	36,569	683,000	23,696	981,000	126,183
Arkansas.....	278,000	171,785	9,162,000	6,313,710	4,289,000	73,875	2,082,000	53,072	672,000	33,000	1,219,000	126,183
California.....	24,000	69,331	3,988,000	3,015,337	1,827,000	33,100	1,320,000	19,924	218,000	12,553	568,000	126,183
Georgia.....	261,000	237,394	10,897,000	10,914,862	6,920,000	113,670	4,365,000	60,765	1,067,000	50,014	1,645,000	126,183
Louisiana.....	163,000	113,453	5,799,000	4,312,285	2,633,000	52,025	1,988,000	32,038	498,000	22,152	670,000	126,183
Mississippi.....	268,000	250,633	15,829,000	11,384,216	7,812,000	110,358	4,553,000	78,713	1,248,000	53,244	2,216,000	126,183
North Carolina.....	452,000	308,792	19,383,000	14,002,000	10,097,000	154,756	5,994,000	84,282	1,336,000	57,947	2,051,000	126,183
Oklahoma.....	291,000	217,934	11,421,000	8,641,001	5,245,000	103,339	4,262,000	56,674	642,000	43,233	1,282,000	126,183
South Carolina.....	34,000	20,394	12,088,000	8,563,644	5,845,000	98,979	3,761,000	80,779	679,000	49,088	1,583,000	126,183
Tennessee.....	101,000	165,836	9,294,000	6,088,000	4,982,000	68,503	3,978,000	56,156	824,000	33,886	1,357,000	126,183
Texas.....	1,832,000	1,322,034	68,925,000	48,673,594	33,322,000	614,637	23,412,000	4,378,000	384,697	4,378,000	33,886	126,183
All other states.....	131,000	86,641	4,736,000	3,409,779	2,438,000	36,722	1,446,000	27,463	255,000	14,422	597,000	126,183
1873.....	4,336,000	3,241,557	\$173,254,000	135,722,995	\$94,818,000	1,487,067	\$59,037,000	943,773	\$12,200,000	584,177	\$17,199,000	8,572,249
1872.....	3,531,000	3,007,717	136,974,000	124,063,298	71,508,000	1,354,604	49,388,000	936,990	8,949,000	382,647	6,619,000	12,215,285
1871.....	5,971,000	4,069,166	156,513,000	174,558,000	84,650,000	1,736,000	58,298,000	1,256,000	10,059,000	422,226	3,506,000	12,286,360
1870.....	5,074,000	4,012,704	352,138,000	161,529,000	209,668,000	1,817,000	119,039,000	1,143,000	11,095,000	584,146	12,336,000	12,286,360
1869.....	5,365,000	4,178,598	385,580,000	171,960,000	227,316,000	2,170,000	118,119,000	1,137,000	17,917,000	589,226	22,258,000	23,527,978
1868.....	5,365,000	4,178,598	385,580,000	171,960,000	227,316,000	2,170,000	118,119,000	1,137,000	17,917,000	589,226	22,258,000	23,527,978
1867.....	5,113,000	4,479,176	390,736,000	174,996,000	217,062,000	2,008,000	97,352,000	936,000	18,678,000	1,060,802	26,604,000	13,487,331
1866.....	1,917,000	1,022,313	187,192,000	188,000	153,191,000	2,225,000	74,586,000	969,000	13,944,000	1,273,345	45,133,000	21,198,086
1865.....	7,184,000	5,779,665	180,260,000	167,110,000	87,940,000	1,923,000	53,860,000	1,220,000	34,000	889,577	35,534,941	57,755,080
1864.....	6,385,000	4,847,828	152,880,000	229,260,000	80,540,000	2,648,000	57,740,000	1,677,000	8,450,000	820,274	6,150,000	42,448,870
1863.....	1,014,000	5,519,308	132,230,000	85,750,000	81,920,000	2,220,000	57,000	1,210,000	1,480,000	669,087	27,728,411	33,98,987
1862.....	6,104,000	4,519,308	132,230,000	85,750,000	69,100,000	1,989,000	45,370,000	1,540,000	7,450,000	7,450,000	4,031,032,564,046	7,450,000

<sup>a</sup> Relates to crop of preceding year.

TABLE LXIX.—QUANTITIES OF THE SEVERAL PRODUCTS OBTAINED PER TON OF SEED CRUSHED, BY STATES, FOR THE YEARS ENDING JULY 31, 1922, 1923, AND 1924

State	Products obtained pounds														
	Total			Crude oil			Cake and meal			Hulls			Linters		
	1924	1923	1922	1924	1923	1922	1924	1923	1922	1924	1923	1922	1924	1923	1922
United States.....	1,884	1,903	1,900	296	309	309	918	918	901	569	582	623	101	94	67
Alabama.....	1,900	1,884	1,878	321	311	308	911	921	889	571	568	620	97	84	61
Arkansas.....	1,864	1,923	1,889	284	312	305	860	896	856	618	623	663	102	92	65
Georgia.....	1,896	1,882	1,900	316	317	321	958	957	901	512	504	609	110	104	69
Louisiana.....	1,869	1,874	1,882	285	310	314	917	922	916	565	554	589	102	88	63
Mississippi.....	1,896	1,901	1,896	329	330	329	850	880	880	606	595	617	111	96	70
North Carolina.....	1,868	1,875	1,884	322	333	320	941	905	943	513	549	555	92	88	66
Oklahoma.....	1,850	1,879	1,911	277	273	290	948	943	928	522	552	624	103	111	69
South Carolina.....	1,876	1,893	1,894	311	322	315	959	928	912	490	523	580	116	120	87
Tennessee.....	1,891	1,894	1,879	276	315	306	826	853	838	677	632	671	112	94	64
Texas.....	1,889	1,930	1,917	282	295	293	927	947	916	582	597	648	98	91	60
All other states.....	1,893	1,906	1,933	309	310	324	888	892	909	806	624	636	90	90	64

TABLE LXX.—NUMBER COTTON SEED OIL MILLS AND THEIR DISTRIBUTION

State	Total number of cotton seed oil mills	Number of cotton seed oil mills crushing—					
		Less than 1,000 tons	1,000 but less than 2,000 tons	2,000 but less than 5,000 tons	5,000 but less than 10,000 tons	10,000 but less than 20,000 tons	20,000 tons and over
United States.....	532	53	56	167	164	75	17
Alabama.....	33	6	6	14	4	3	
Arkansas.....	29	4	2	9	9	5	
Georgia.....	52	13	8	13	12	5	1
Louisiana.....	20	2	3	6	5	4	
Mississippi.....	41	3	2	16	13	6	1
North Carolina.....	58	1	7	28	15	6	1
Oklahoma.....	42	7	5	12	12	6	
South Carolina.....	47	7	12	16	7	5	
Tennessee.....	19	..	4	2	9	1	3
Texas.....	174	9	5	48	72	32	8
All other states.....	17	1	2	3	6	2	3

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